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INTERNATIONAL LANGUAGE FOR AVIATION

A Review of Air Force Sponsored Research from 1952 to 1961

Stephen E. Stuntz

Technical Documentary Report no. ESD-TDR-62-14
February 1962

Operational Applications Laboratory
Deputy for Technology
Electronic Systems Division
Air Force Systems Command
L. G. Hanscom Field, Bedford, Mass.

Project 7686

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ABSTRACT

The administrative provisions for this research are briefly reviewed.

In Part I, reports of research are categorized and discussed under these topics:

- Communication in English with non-native English speakers
- Comparative effectiveness of ICAO and US-UK phraseologies
- Operational communications
- Voice transmission of numerals
- Basic and theoretical findings
- Miscellaneous secondary developments

A bibliography of 74 references comprises Part II.

An annotated bibliography of all reports, arranged by contracts, appears as Appendix I.

Reviewed and approved for publication.

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INTRODUCTION

Background. Research on the language of voice procedures in Air Force operations was initiated in May 1952 by a contract (AF18(600)-316) between the Operational Applications Laboratory, ARDC, and The Ohio State University Research Foundation. The statement of work directed attention to problems of intelligibility in air-to-air, air-to-ground and point-to-point voice communication. This contract terminated at the end of November 1955; expenditures totaled \$148,000.

A technical requirement promulgated by Hq. ARDC (TR 136-55 dated 15 November 1954) responding to a Hq. USAF operational support requirement for language phraseologies and voice procedures to be used by NATO, SEATO and USAF operators, gave rise to Task 76813 of Project 7681, Auditory Presentation of Information. A new contract was negotiated between Operational Applications Laboratory and The Ohio State University Research Foundation specifying research and development of an English-based international language for aviation. This contract (AF19(604)-1577) became effective on 1 December 1955 and was completed 31 May 1958, at a total cost of \$125,000. During the life of this contract, considerable emphasis was laid on satisfying the communication requirements of the international civil aviation community as well as of the military. The contractor was required to co-ordinate with, and present research findings, to ICAO, Montreal, and CAA (now FAA), Washington, to obtain reaction and acceptance for use by civil as well as military airways users.

Under Hq USAF Operational Support Requirement 179 of 17 August 1956, Hq ARDC Operational Requirement 220 of 11 September 1956, and Hq USAF Operational Support Directive 92 of 7 November 1957, a new ARDC project was established specifically to enable research upon "a simplified aeronautical language for air-air and air-ground radio-telephone voice communication." It was specified that this language would be essentially English; must be compatible with the language habits of NATO and SEATO forces; and should utilize present Air Force phraseologies and procedures wherever possible. Three specific tasks were formulated under Project 7686:

Task 76861: Air Defense and Tactical Control Communications-development and evaluation of phraseologies and procedures specific to control of air defense and tactical combat operations in joint and combined US-NATO-SEATO

missions.

76862: Air Traffic Control and Air Navigation Communications - development and evaluation of language and procedures employed in enroute control and transmission of navigational information, supporting joint and combined operations.

76863: Terminal Air Traffic Control and Meteorological Data Communications - development and evaluation of vocabulary, phraseologies and procedures required in approach, landing, take-off, and departure control (including visual and instrument flight conditions), and in transmission of weather information, for use in multi-language military air operations.

To the documentation was added the injunction that current US practices be preserved wherever feasible, that research plans be governed by current and proposed ICAO standards as far as possible, and that full consideration be given to applying experimental findings to the development of training aids and manuals.

Research under Project 7686 was carried almost entirely by contract between Operational Applications Laboratory and The Ohio State University Research Foundation's Psycholinguistics Laboratory; for the period 8 September 1958 to 31 March 1960, AF19(604)-4575 at a cost of \$100,000; from 1 April 1960 to 15 May 1961, AF19(604)-6179 at a cost of \$61,000.

Hq ARDC was notified by Hq USAF on 9 November 1961 of the formal cancellation of Operational Support Directive 179 due to termination of the NATO requirement for an international voice radio language for air operations. With completion of AF19(604)-6179 all research has ceased, and Project 7686 has been closed. During the nine years of contract effort, approximately \$434,000 of Air Force funds was spent.

General Orientation of Research. Preliminary investigation established that there was not available sufficient basic knowledge about the effect on air traffic control communication of differences in the language backgrounds of operating personnel. Designing and evaluating the required phraseologies could not be undertaken until some experimentally based approach could be formulated, taking into account the language characteristics of the various nations involved. Therefore most of the research effort has been concerned with working out fundamental principles applicable to

operational communications in multi-language environments.

Plan of this Review. Part I presents and interprets findings derived from research supported by the aforementioned contracts, and includes pertinent results from other Air Force sponsored sources. Part II consists of bibliography of all research reports cited in Part I, listed in order of reference.

Part I is divided into these topics:

1. Communication in English with non-native English speakers
2. Comparative effectiveness of ICAO/US-UK phraseologies
3. Operational communication
4. Voice transmission of numerals
5. Basic and theoretical principles
6. Miscellaneous secondary developments (experimental) techniques, equipment, word lists)

PART I: RESEARCH RESULTS AND THEIR INTERPRETATION

1. Communication in English with non-native talkers and/or listeners. Foreign personnel attending US Air Force schools for technical and flight training must be adequately familiar with English before training can be initiated. Two tests of ability to comprehend spoken English were given for comparison to 44 trainees at Lackland AFB; this group represented 25 non-US nationalities (1). * The tests were Form C, Lado Test of Aural Comprehension, and Oral Section of Form B, MDAP English Proficiency Examination. While the two sets of scores showed highly significant intercorrelation ($r = .548$), trainees scored significantly higher ($t = 8.02$) on the Lado than on the MDAP. It was concluded that the Lado is more suitable where administrative simplicity and brevity are paramount in assessing foreign nationals' general English language proficiency but that the MDAP is preferable where specific competence in aviation terminology is more important.

Effective communication in English among foreign nationals is often hampered by deviations from customary pronunciation patterns. To standardize on the use of General American by all nationalities in a multi-lingual group of talkers (Oriental, Central American, European), a before-and-after comparison (2) was run to determine the value of specific coaching on current pronunciation of aviation terms. Foreign talkers' performance was evaluated by native US listeners, as to both correctness and intelligibility. It was shown that simple drilling by a competent instructor made a significant improvement in talkers' "correctness" of pronunciation, as judged by experienced speech specialists, and in intelligibility of American-English terms, as measured by group listening tests.

In teaching spoken English to foreign nationals, particularly when a specific technical vocabulary is to be used (as in air traffic control), it is desirable to represent the sounds of English in written form by means of phonetic spelling. Training in correct US-English pronunciation can be expedited if words are presented in the spelling systems (orthographies) of students' own native languages. Five hundred common aviation communication words and twenty-five phrases routinely used in air traffic control were compiled in their spoken English equivalent spellings, in Chinese, Dutch, French, German, Italian, Japanese, Korean, Spanish and Thai. A Greek orthography has been recently added (3). In an experimental

* Numbers in parentheses identify reports listed in Part II, Bibliography.

evaluation, this training aid was found to yield significant improvement in pronunciation by each of the language groups, as compared with reading orally from a list of the same terms printed only in English.

It has been noted that foreigners' greatest difficulty in understanding spoken English appears to be related to discrimination of differences between vowel sounds, as pronounced by native speakers of US English. An experimental test of ability to detect differences between vowels, as spoken by General American talkers, was devised and evaluated (4). It is proposed for diagnosing needs for specific phonetic instruction and measuring progress in language training.

While modification of foreign talkers' speaking habits to conform with standards of English pronunciation is important to successful communication, it has been observed that native English listeners adapt to patterns of accent distortions. To a considerable extent this adaptation appears to depend on recognition of vowel sounds as spoken by non-natives. The effect of one non-US accent on the intelligibility of English one-syllable words was examined experimentally (5), to determine predictability of error in communication, and also to identify the vowel sounds requiring particular emphasis during training. Besides achieving these goals, the study also revealed that vowel combinations (diphthongs) are more subject to degradation than are the individual vowels.

In air traffic control communication approximately twenty percent of all voice transmissions is numerals (23); it is critically important to air safety that these be maximally intelligible. A recent study (38), discussed later, established a hierarchy of intelligibility confusions among numerals; two and three emerged as most often confused of all ten digits. A later series of experiments (6) shows that this particular confusion is largely independent of foreign accent distortion effects.

2. Comparative effectiveness of ICAO/US-UK phraseologies. The ICAO word spelling alphabet was adopted for the stated purpose of meeting the linguistic needs of non-English speaking member states, and was intended to improve upon the US-UK alphabet widely used during World War II and following. Considerable research was conducted to test, confirm and modify various of the letter-words proposed for adoption into the final form of ICAO alphabet, which was also expected to be utilized by NATO, and eventually SEATO forces. Thus a word-

spelling alphabet was to become the first truly international language for air operations. During the early stages of formulating the ICAO alphabet, several alternatives were proposed for certain letter-words, for example: for N - November, Nugget, Notam, Nectar, Nylon; for C - Charlie, Cocoa; for V - Vampire, Victor; and so on. Questions arose as to the intelligibility of the entire ICAO alphabet and the several variants proposed for some of the letter-words, as to user acceptance or preference for ICAO versus US-UK alphabets, and as to the feasibility of using both alphabets concurrently. A series of experiments (7 through 14) tested the effects of various national accents on intelligibility of US-UK and ICAO alphabets, including pronunciational variants for numerals as well as letters. It was concluded that the ICAO alphabet produced more intelligible communication in a multi-language environment, that Charlie should replace Coca for C, X-ray should replace Extra for X, Mike should replace Metro and Maximum for M, Uniform should replace Union for U, November should replace Nugget and Nector for N, and Victor should replace Vampire for V. Also, for numeral 3 the more intelligible pronunciation was found to be "three" instead of "tree", "five" for 5 instead of "fife" and no gain was made by pronouncing numeral 9 as "niner." On the matter of preference for one alphabet system over the other, two experiments (8 and 14) showed that after brief training on the ICAO alphabet, airmen and students previously accustomed to the US-UK alphabet adapted satisfactorily both in attitude and facility for using the ICAO format. The problem of concurrently using both US-UK and ICAO alphabets for air-ground and air-air communication was attacked in one study (15), which clearly demonstrated that greater efficiency results from employing one system only. This study also showed that foreign background talkers' intelligibility improved significantly when they shifted from US-UK to ICAO alphabets.

It was anticipated that the language habits of different nations would impose a variety of pronunciation upon the ICAO alphabet words, likely to affect the reliability of communication. An articulation experiment (16) employing talkers of Latin, Slavic, and Germanic language backgrounds, reading ICAO word-groups to listeners of US, Oriental, Arabic, Latin, Slavic and Germanic backgrounds. Test transmission included alternative pronunciations for several words, and also the Fox/Foxtrot alternative words for letter F. Results indicated that pronunciations normal to the habits of user (ICAO) nations did not impair communications significantly. That is, the recognizable features of "foreign" accent did not distort intelligibility appreciably.

3. Operational Communications. It has long been customary to transmit voice-radio information on flight operations by means of "standardized" messages; thus given operational events are coupled to given communication events, enhancing predictability for the listener and therefore protecting reliability. The practice has been to select the appropriate terms from a limited, widely agreed upon vocabulary, and arrange them in a prescribed order. With establishment of ICAO and NATO, the form for these messages came under dispute: whether the widely used "telephese" style should give way to a full sentence structure approximating conversational usage. A detailed experiment (17) undertook to test whether the reliability of communication over a moderately noisy circuit would be materially improved by the full sentence form. Talkers of five nationalities transmitted messages in both telephese and full sentence styles concerning seven different types of flight operations to native US listeners, who attempted to reproduce in detail the contents of each message. Results showed no significant difference in favor of either style. This finding, with previous observations that telephese saves an average of 14% transmitting time over full sentence (17, ref. 1), reaffirmed the recommendation to continue the use of telephese. A later study (18) confirmed and extended these findings to include non-US listeners, and also reported that an Air Force sponsored seminar on air control communication strongly preferred the current (telephese) form because of its brevity and clarity. A third paper (19) proposes some bases for organizing and evaluating phraseologies; the aim has been to discover the fundamental principles used in radiotelephone airways communication, and by relating them to the phonemic characteristics of typical non-English languages, evolve rules for an International Language for Aviation. Consideration is given to training as well as operational problems.

Considerable attention has been given to examining the operational aspects of air traffic control communication in a multi-language setting. Current and proposed procedures were investigated, both empirically in the field and experimentally in the laboratory, to determine their adequacy to operating requirements. A recent analysis of more than 8,000 separate air-ground transmissions, assembled from traffic control facilities at four international airports (Idlewild, Miami, Mexico City and Accra) (20), infers several functional categories and purposes for routine communication, and compares the performance of native and non-native English speaking talkers at both ends of the air-ground link. Another study of the same communication samples (21) examined the rates at which ground controllers and pilots speak under typical operating conditions, and noted that native

English speakers characteristically use significantly slower rates when communicating with non-native speakers, controllers or pilots. It is also noted that both parties apparently automatically adjust their talking rates to meet the perceived needs of listeners. A laboratory experiment (22) studied the impact on intelligibility of five different message formats (all derived from current or proposed procedures) when speaking rate was varied from normal to fast to artificially slow-paced; normal rate and manner of phrasing were concluded to be most effective for all five message formats.

Extensive experience in air traffic control has shown certain elements of voice communication to be critically related with operational safety - for example, altitude, distance, position and navigation reports or instructions, including estimated and achieved times of arrival and departure. All of these include numbers, and weigh heavily in controllers' decisions regarding vertical and horizontal separation of aircraft. The actual proportions of vocabulary elements appearing in typical air-ground messages have been reported in a word count study which sampled recorded traffic messages at three high density domestic and two international facilities in continental US (23). Out of approximately 250 terms used, the cardinal numbers occur almost 19% of the time, with the heaviest loading in radar approach control communication, approximately 23%. Thus it may be recommended that maximum effort to protect intelligibility and distinguishability of traffic control communication be specialized on spoken numerals.

The value of formal procedures for selecting and arranging word elements in voice messages has been tested experimentally in several ways. Within the context of air defense communication, the effect of foreign accented English on a proposed list of procedure terms was measured with reference to various types of noise backgrounds (24); it was found that "white" or thermal noise impinges most seriously on the intelligibility of foreign-accented English, received by native US listeners. Another experiment (25) showed that inclusion of "polite" terms, such as prefatory "please," added nothing to message intelligibility, and also that a number of "standard" expressions (immediately, above, below, hear, etc.) were inferior to proposed alternates (at once, over, under, read, etc.) when transmitted in moderately noisy systems. Various sequences of terms widely used in air defense surveillance messages were tried experimentally (26); both a "standard" order and several others, approaching randomness, were compared. Results indicated that communicators develop habits of flexibility in adapting to varying arrangements of familiar terms, thus tending to preserve reliability of communication despite uncontrolled deviations from standard practice.

At a time when the international "Q-code" was being considered for inclusion in aviation voice procedure, there was dispute as to whether the original telegraphic form (QXX) should be maintained, or whether it should be augmented with an additional letter Q (QXXQ). A series of experiments (27) involving transmission by talkers of six nationalities to US listeners showed no significant gain by including the extra Q, even under severe noise conditions, using both the US-UK and the ICAO word spelling alphabets. It was also found that, in the three letter groups, the intelligibility of second and third letter elements deteriorates as compared with the first element. Three methods of giving weather and aircraft position reports were compared under moderate circuit noise conditions: 1) use of tag words before each group to identify the type of data to follow; 2) use of no tag words, groups separated only by distinct pauses; and 3) use of no tag words with data groups read as fast as possible (28). As measured by listeners' write down responses, the second procedure was found to be significantly more accurate; it was found desirable to include some fast telling experience during training, to extend listeners' capabilities.

Early in the effort to adapt English phraseologies and procedures to the requirements of foreign background speakers, a question was raised regarding voice emergency signals; the traditional SOS and MAYDAY were compared experimentally as to intelligibility transmitted by foreign speakers (29). MAYDAY was found to be significantly easier to understand through heavy noise.

The possible substitution of non-verbal communication methods was assessed for routine flight line communications, recognizing that much information can be transmitted by the finger spelling methods utilized by deaf mutes. The method was considered of possible value where high noise levels prevail and where sender and receiver can maintain visual contact. To this end, a comprehensive catalog (30) of flight line hand signals was compiled, along with some proposed modifications, including some deaf mute alphabet additions. This report also contains suggestions for a quick reference manual and several training aids. An experimental analysis of intelligibility/confusability versus sender-receiver separation was subsequently made (62) for the deaf mute finger spelling alphabet.

The evolution of the present ICAO word spelling alphabet has been described in detail, with reference to experimental methods and findings which led to recommendations of various items and pronunciations (31). The report also contains

discussions of limitations and communication efficiency of the alphabet, and lists 200 word spelling alphabets compiled from international sources.

4. Voice transmission of numerals. In recognition of the importance of correct transmission of numbers by voice for both civil and military air operations, a series of studies was undertaken to establish the most effective techniques for speaking them, under conditions of circuit noise and foreign accent. Two closely related experiments (32, 32a) showed the single numeral method (99 = NINE-NINE; 1234=ONE-TWO-THREE-FOUR) superior to all others, regardless of talker-listener language background.

It has been suggested that number intelligibility might be improved by using some standardized technique of repeating transmissions, perhaps sacrificing time for intelligibility. Several recommended procedures were scrutinized experimentally (32) using three numeral groups as subject material. The final conclusion was that none of the three repetition methods under consideration offered any significant improvement over saying number groups once in single digit form, regardless of nationality of talker and listener. Repeat formats used were: 324-THREE-TWO-FOUR, THREE-TWENTY-FOUR, THREE HUNDRED TWENTY-FOUR.

Four additional methods were tested subsequently (33); 468=FOUR-SIX-EIGHT, I SAY AGAIN, FOUR HUNDRED SIXTY-EIGHT; FOUR HUNDRED SIXTY-EIGHT, I SAY AGAIN, FOUR-SIX-EIGHT; FOUR HUNDRED SIXTY-EIGHT, I SAY AGAIN, FOUR HUNDRED SIXTY-EIGHT; and FOUR-SIX-EIGHT, I COUNT FOUR, TWO-THREE-FOUR, SIX, FOUR-FIVE-SIX, EIGHT, SIX-SEVEN-EIGHT. (The last has been called circle counting.) Regardless of background noise and foreign-accent distortions, the last method proved superior to the other three.

Pronunciation of numeral words has also received some attention (34). One-, two-, three-, and four-digit groups were spoken by US and foreign talkers, to panels of US listeners. With US talkers and listeners, the most intelligible pronunciations were: 0=ze-ro, 1=uuh-wun, 3=th-r-ee, 6=siks, sikser, suhsiks; 7=sev-ven. With foreign talkers and US listeners, the most intelligible were: 0=ze-ro or zero, 2=too or tuh-too, 4-for, 5=fif-iv, or five, 6=siks or sikser, 8=ait or a-ait. This study further confirmed earlier findings (30 and 31) that single digit number saying was superior to all other methods.

In reporting altitudes and courses or compass headings, multiple numeral groups usually occur, often containing repetitions of the same digit in sequence (e.g., 15500, 725). Several renditions of this type of information were tested (35); where the same digit occurs two or three times in succession (511, 5111), it made no difference whether talkers said FIVE-ONE-ONE and FIVE-ONE-ONE-ONE or FIVE-DOUBLE-ONE and FIVE-TRIPLE-ONE. Where even hundreds and thousands occurred (500, 15000), the most easily understood format was FIVE-ZERO-ZERO or ONE-FIVE-ZERO-ZERO-ZERO. A further examination of these findings in another experiment (36) showed that this same format was as good as or slightly better than saying FIVE-DOUBLE-ZERO or ONE-FIVE-TRIPLE-ZERO.

The context surrounding a particular message item often affects intelligibility; thus the question was asked, when letters and numbers are grouped together in voice transmissions, what is the effect on readability of numbers? To determine the interactive effects of ICAO alphabet words on the intelligibility of numerals, a brief experiment was performed (36) which grouped all 26 letters in various combinations with the 10 numerals plus three numeral variants (TREE, FIFE and NINER in addition to THREE, FIVE and NINE). No significant effects were discovered between letter words and spoken numerals; however it was shown that ZERO is more intelligible for number 0 than OH; that THREE and FIVE are every bit as intelligible as TREE and FIFE; and that there is no choice between NINE and NINER.

Extensive interview and anecdotal evidence from pilots and controllers, supplemented by experimenters' personal observations of flight operations at domestic and international air traffic control facilities, as well as some incidental research discoveries (37) suggested that there might be some inherent characteristics peculiar to English numeral words which cause certain ones to be predictably confused with certain others. This notion was exhaustively studied in two separate investigations (38 and 6) which brought to light serious and systematic confusions between various pairs of single digit words (TWO-THREE and THREE-TWO being the most common), and showed that the vowel structure (OO-EE, EE-OO) was responsible. These findings will be discussed more fully in the following section.

5. Basic and Theoretical Findings. Intrinsic intelligibility and confusability of the ten English numerals, plus six variant pronunciations (3=TREE, FREE; 4=FOW-ER; 5=FIFE; 9=NINER; 0=ZERO), were extensively tested against varying

noise and foreign accent conditions (38). A stable order of intelligibility was found, independent of either noise or accent effects; ranging from highest to lowest it runs FIVE, OH, SEVEN, ONE, SIX, FOUR, NINE, THREE, EIGHT, TWO. The principal confusions were: ZERO-4, OH-8, ONE-9, TWO-3, THREE-8, TREE-2, FREE-2, FOUR-0, FOW-ER-0, FIVE-9, FIFE-9, SIX-8, SEVEN-1, EIGHT-3, NINE-1, NINER-1. (Capitals indicate the word which was spoken; each numeral represents listeners' written responses. When the same numerals were re-tested using a transmission system sharply cutting off all frequencies above 2800 cycles per second, a small but statistically significant degradation of intelligibility was found.

The above discoveries of confusions between 2=TWO and 3=THREE, FREE of TREE led to a study (6) of the effect of consonants on the intelligibility of phonemes /u/(oo) and /i/(e); the object was to test whether something inherent in the vowels themselves accounts for the confusion of 2 and 3, or whether the beginning and ending consonants surrounding the vowels are responsible. Test of the effects of five different foreign language accents were included in the experimental design, so as to ascertain the extent to which systematic variations of pronunciation might also affect discrimination of the two vowel sounds. While the interactions between vowels, consonants and foreign accents complicate the results, this experiment seems to point the way toward improving intelligibility of 2 and 3 by substituting more recognizable consonants for T as in two and THR as in three.

An earlier series of experiments (39) set out to identify confusions among phonemes, both vowels and consonants, prevalent in English, both native US and foreign accented. List of test words were compiled from several word spelling alphabets, both civil and military; they were read and listened to by observers from 27 different countries. Final results, narrowed down to a treatment of vowels only, noted that the most confusable sounds were /i/ (e) and /u/ (oo). Several phonetic rules were formulated for calculating confusability of individual words in a list, from error scores on write down tests of intelligibility.

On an entirely different approach, improvement of communication in heavy noise was sought by introducing an interaural echo effect. This was accomplished by splitting an incoming signal channel into two subchannels, one for each ear, and inserting into one subchannel a sixty-millisecond delay. Several experiments (40) found definite improvement in intelligibility of letter number groups when the echo effect

was introduced. However, the advantage did not hold equally for both ears: when the delayed subchannel was presented to the right ear, intelligibility was significantly better than when presented to the left. The apparent discrepancy was not accounted for by interaural differences in hearing sensitivity; all listeners were reported to have clinically normal hearing in both ears.

It has been thought that certain emotional states work to enhance intelligibility of spoken language. To attack this assertion experimentally, several experienced actors read lists of two digit numbers to groups of listeners, simulating the emotional states of sadness, joy, and anger, as well as a neutral or emotion free condition (41). It was concluded that emotional coloring adds nothing to intelligibility, nor does it apparently detract; thus a talker may be equally intelligible to listeners under any of several types of emotional stress.

The use of talker-listener intelligibility tests in communication experiments is often complicated by learning effects which are unavoidable when dealing with selected samples of language presented repeatedly under experimentally controlled conditions. The need to define parameters and limits of these learning effects produced a series of experiments (42), which showed definitely that amount and kind of training are primary variables in listener performance on intelligibility tests.

Relationship between the acoustical characteristics of speech and the means whereby listeners extract meaning from them has long occupied the attention of linguists, psychologists and engineers. It has been surmised that human auditory perception is especially responsive to time variations in frequency and amplitude of sounds; with particular regard to speech it has been thought that intelligibility may hinge critically on detecting the subtle transitions between individual sounds, as well as on perception of the individual sounds (phonemes) themselves. To examine this concept in detail a series of experiments was run to see what influence different magnitudes of such transitions might have on the differentiation of consonant-vowel-consonant monosyllables (43). Listeners were required to identify consonants, vowels, and inter-phonemic transitions in varying amounts of background noise, as a function of both the magnitude and direction of frequency-amplitude transition through time. It was found that listeners do indeed recognize different degrees of inter-phoneme transition, but

that they respond most accurately only to either very small or very large magnitudes, being most likely to confuse a medium magnitude with either of the others, or to miss it altogether.

A related study was undertaken to determine the extent to which certain language sounds (in this case, vowels) might obscure or "mask" words which are otherwise highly intelligible (44). It was found that prolonged vowel sounds with a preponderance of sound pressure concentrated between 700 and 1000 cycles per second produced the most deleterious effects on intelligibility, and that a given vowel sound in a particular word was not most effectively masked by that same sound presented in prolonged form as a background noise.

The relationship between phonetic structure and intelligibility of words has received further attention in a practical communication problem involving evaluation of microphone transducers. For communication in high noise, it was proposed to use a type of microphone which could be inserted into the ear canal, thus reducing the pickup of ambient noise. A comparison between this device and a standard lip microphone was the subject of an experiment (45), the phonemic composition of test words being the crucial parameter for measuring intelligibility. It was found that the type of ear microphone proposed produced significantly poorer comprehension of specific vowel sounds than did the lip microphone, even under extremely unfavorable conditions of ambient background noise.

Since discovery that acoustic features of different speech sounds determine their intelligibility (and also their confusability with each other), the question has been asked, "Which sounds of normally spoken English are inherently the most and least intelligible, and what are the confusions among those sounds"? Three closely related experiments (46, 47, 48) sought partial answers: in the first (46), various vowel sounds were read to listeners, under several levels of noise and also in quiet; from their written responses differential intelligibility values were assigned and a confusion matrix constructed. In the second (47), consonants only were tested, in like manner except that each was preceded or followed by a single vowel sound (short i). In the third, an experimental test of single vowel intelligibility was constructed and compared with the intelligibility of lists of phonetically balanced (Harvard PB) word lists, the object being to devise a standardized instrument for measuring at least three dimensions of voice communication - talker

intelligibility, listener perception (both of these applicable to problems rising from differences in language backgrounds), and equipment characteristics, at the same time avoiding the complications associated with word meanings or vocabulary differences.

As mentioned before (paragraph 3, page 8), a listener's expectation of what he might hear often affects his judgment of what he reports he does hear. This phenomenon, significantly related to practical voice communications, was the subject of three investigations (49, 50, 51) more or less related to each other. In the first, the effect of systematically varying sequences of syllables and words on listeners' ability to construct intelligible messages was studied. In the second, listeners of differing language backgrounds were tested for their ability to discriminate similarities and dissimilarities between written and voice messages. The third experiment examined the effects of expectation upon listeners' responses to various types of intelligibility test formats. All three of these studies confirmed the hypothesis that expectation, based on prior experience, does indeed have a determining effect on listeners' choices of responses in a voice communication situation; the last one sought test forms whose results were least susceptible to contamination by "response set."

6. Miscellaneous secondary developments.

A. Training aids. One of the early tasks performed by the Ohio State University Research Foundations' Psycholinguistics Laboratory under this sequence of contracts was development of a kit of training materials and communication exercises for air defense forward- and cross-telling and scope-to-plotter reporting (52).

B. Equipment evaluation and evaluation techniques. In connection with the general objective of this research program, improvement of voice communication in multi-language environment, several equipment oriented experiments were undertaken. These were concerned mainly with protecting the input end of a voice communication system from high ambient noise levels surrounding the talker. A whole series of studies examined the use of special microphones located at various positions around the talker's head and neck (53, 54, 55, 56, 57, 58) and detailed intelligibility test comparisons were made between several Air Force standard microphones and experimental transducers inserted into the talker's ear canal (53 through 57). Generally speaking, no significant improvement in speech-to-noise pickup was

achieved by the special anatomical microphones in high level noise. The same comment applies also to an experimental bone conduction transducer used as a microphone, and located at various points on the bony structure of the talker's skull (57). Further inquiry was made into the possibility of speech-sound pickup by contact microphone at 16 different locations on head and neck (57a). Ultimately some recommendations were worked out regarding a special ear-mouth combination microphone receiver, (59) and tested by means of word list intelligibility procedures, in comparison against standard Air Force equipment. In another series of experiments, means were sought to relieve problems of weight, discomfort, and hygiene attendant upon use of early AIC-10 microphone and headset equipment; comparative articulation testing was conducted on this and some proposed alternative equipments (60) in flight on several types of aircraft.

C. Specialized instrumentation. A research requirement for specialized apparatus to measure and control speech-to-noise conditions for laboratory experiments resulted in the design and fabrication of an electronic device (61) which may find application both in other research and in training.

D. Specialized communication materials. Pursuant to requests by Hq USAF, the contractor developed lists of one syllable English words, including proper names and family names (except those of race horses); in the first version (58) words were listed alphabetically according to vowel, with beginning and ending consonants set apart, and with pronunciation variants indicated. This material was later refined and reorganized (59).

E. Special voicing techniques. Several novel techniques of voicing operational communications were tried experimentally, to see whether they might achieve any practical gain in intelligibility over customary practices. Noting the prevalence of certain tonal patterns in native American speech, experimenters manipulated vocal inflection during the transmission of two unit signals (pairs of vowels only; two digit numbers; pairs of ICAO alphabet-words; paired word-number combinations) (63). It was concluded that flat and rising inflections, imposed on both members of each pair, were more effective than other combinations, but that variation in type of transmission (see above four pairs) offset any real communication gains. Another study (64) compared the use of hyponasality, hypernasality and normal voice quality on the intelligibility of two digit numbers, and showed that normal delivery was best throughout. Research from several sources not included in this discussion has shown that repetition of message elements often enhances intelligibility under noisy communicating

conditions; this observation was extended experimentally by the Ohio State laboratory to an investigation of several types of controlled, intentional stuttering. It was found that a technique in which initial sounds of operational words and numerals are repeated once ("single-bounce"), for instance, 2=kuh-two, cleared=kuh-cleared, materially improves intelligibility when background noise is deleteriously high; recommendations for further research and specific training of personnel were made regarding this technique (65, 66, 67, 68).

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**APPENDIX I: Annotated Bibliography of Reports,
Arranged by Contracts**

Contract AF 18(600) 316

Moser, Henry M., Dreher, John J. COMPARISON OF US-UK AND ICAO PHONETIC ALPHABETS. HFOLR Memo Rpt. no. 3, December 1952.

Reports intelligibility comparison of US-UK and ICAO (old form) at S/N=0 and -5db. Talkers of American, British, French, Spanish, German and Scandinavian nations; listeners were American, British, German, Spanish, Thai, French, Indian, Scandinavian, Greek and Japanese. At -5db S/N ICAO alphabet showed slight (non-significant) superiority over US-UK. Analysis of confusion-matrix developed from data leads to recommendation for changing EXTRA for X to X-RAY, COCA for C to CHARLIE, METRO for M to MAXIMUM.

Moser, Henry M., Dreher, John J. RESEARCH ON THE LANGUAGE OF VOICE PROCEDURES - AIR DEFENSE TRAINING AIDS. OSURF Project 519, Report no. 2, June 1, 1953.

Describes kits of training materials for Air Defense scope-to-plotter, forward-teller and cross-teller procedures; includes pictorial, written instructions and tape-recording containing examples of correct and incorrect voice-communication practices. No bibliography.

Moser, Henry M., Dreher, John J. RESEARCH ON THE LANGUAGE OF VOICE PROCEDURES - COMPARISON OF UNITED STATES-UNITED KINGDOM AND INTERNATIONAL CIVIL AVIATION ORGANIZATION PHONETIC ALPHABETS. OSURF PROJECT 519, Report no. 3, Part II, June 18, 1953.

US-UK and ICAO alphabets were spoken by two speakers each of U.S., British, French, Spanish, German and Scandinavian nationalities to listener panels composed of U.S., British, German, Spanish, Thai, French, Indian, Scandinavian, Greek and Japanese nationals. Alphabets were presented in randomly arranged three-item groups; the two alphabets were presented in this form separately, i.e., not intermixed. S/N=0, -5, -10, -12, -16db (white noise). Scores were percent correct responses; confusion matrices were also developed. Conclusions: ICAO more suitable than US-UK alphabet for multi-language use; three changes in ICAO alphabet recommended: change EXTRA (X) to X-RAY; COCA (C)

to CHARLIE; METRO (M) to MIKE. Second experiment sought attitude ratings on 7-point scale re: US-UK and ICAO alphabets (individual words). No specific criterion of preference was imposed; raters (mixed U.S. and foreign students at OSU) yielded data concluded by experimenters to signify "attitude.... changes to a neutral stand after a period of training." Third experiment required subjects to First Experiment above to read three-letter groups in either US-UK or ICAO alphabets (whichever came first to mind), as fast as possible, following a pre-test training period in both alphabets. Responses were tape-recorded during experimental sessions and scored in three categories: no. in US-UK, no. in ICAO, no. in neither set. Data showed highly significant dominance in use of ICAO alphabet over US-UK. Conclusion: "subjects were apparently more secure in their ability to use words of the ICAO alphabet than those of the US-UK." Fourth experiment: intelligibility of "Modified ICAO alphabet" (substituted CHARLIE (C) for COCA, MIKE (M) for METRO, X-RAY (X) for EXTRA) was measured at S/N = -10, -12, -16 db, using U.S., German, Spanish, German talkers, with listeners mixed U.S. and foreign as in First Experiment, above. Same was done with unmodified ICAO alphabet. Results showed modified version significantly more intelligible than unmodified, for both foreign and U. S. listeners. Additional tests were run comparing original ICAO against above modification (C, M, X) and against a further modification (Including above C, M, X) and also substituting FOOTBALL (F) for FOXTROT, UNIFORM (U) for UNION, ZEBRA (Z) for ZULU. Data were taken at X/N = -10, -12db, using U. S., British, French, Spanish, German, Scandinavian talkers and U.S., British, French, Spanish, German, Finnish, Indian, Greek, Thai and Japanese listeners. Results favored conclusions recommending modification of ICAO alphabet by substituting CHARLIE for COCA (C), X-RAY for EXTRA (X), MIKE for METRO (M), UNIFORM for UNION (U). Bibliography = 43 titles.

Moser, Henry M., Dreher, John J. RESEARCH ON THE LANGUAGE OF VOICE PROCEDURES - COMPARISON OF UNITED STATES - UNITED KINGDOM AND INTERNATIONAL CIVIL AVIATION ORGANIZATION PHONETIC ALPHABETS. OSURF Project 519, Report no. 6, June 18, 1953.

Intelligibility of US-UK and Modified ICAO (C, M, X = CHARLIE, MIKE, X-RAY) compared in three transmission formats: straightforward use of alphabet in word-spelling; word-spelling by repeating letters of alphabet, prefacing second presentation with "I say again"; word-spelling by

sounding the normal English-alphabetic name of the letter then following with ICAO alphabet equivalent. Native U. S. speaker (one) recorded stimulus materials, which were presented to 20 native U. S. listeners. S/N = -17 db. Intelligibility and confusability scores were derived from data obtained.

Confusability was calculated as

where C_L = confusability of a letter

$$C_L = \frac{N_{\text{sub}}}{TR - F_L} \times 1000$$

N_{sub} = number of substitutions

TR = total no. responses for given letter

F_L = theoretical frequency of the letter

Conclusion: significant differences were found between transmission formats. "I say again" was significantly more intelligible than letter-ICAO format. No bibliography.

Moser, H. M., Dreher, J. J. A COMPARISON OF THE US-UK AND ICAO PHONETIC ALPHABETS. OSURF Project 519, Report no. 3. July 1953.

Articulation tests and tests of user confidence indicate that the ICAO alphabet is in all respects significantly superior to that of the US-UK alphabet, regardless of the nationality of either speaker or listener.

Attitude rating scales after training in and use of both alphabets indicate that no significant preference for either is evinced regardless of the subject's attitude as indicated by the same rating device before such training and use.

Substantial improvement in the efficiency of the ICAO alphabet may be made by the substitution of four words:

COCA changed to CHARLIE

EXTRA changed to X-RAY

METRO changed to MIKE

UNION changed to UNIFORM

Moser, Henry M., Dreher, John J. EFFECT OF CODE GROUP WORD POSITION UPON ERRORS. OSURF Project 519, Report no. 4

October 1953.

Experiments were conducted jointly by Ohio State and British Ministry of Civil Aviation to determine whether the final elements of 3-letter code groups are significantly less intelligible than the first elements, when spoken by U. S. and U. K. air traffic personnel and responded to by listener panels of both nationalities. US-UK and ICAO word-spelling alphabets were compared at $S/N = 10, 0, -5, -10, -12, -16$ db. Second and third elements were found to be significantly less intelligible in both alphabets; it is clearly implied that this is due to "intonation" patterns imposed by talkers. Further experiment attempted to determine an optimally efficient method for transmitting by voice the "Q-code" groups promulgated by International Telecommunications Convention of 1947 and by ICAO Third Session Final Report. Half of the stimulus material contained an additional presentation of the letter Q following each three-letter Q-group. Lists of randomly-arranged 3- and 4-letter groups were recorded by talkers of U. S., Spanish, Japanese, Filipino, Swedish, and Greek origin; listeners were native U. S. $S/N = -22$ db. Conclusion: no significant improvement results from addition of letter Q to existing Q-signal groups.

Further finding from first experiments: diminishing S/N contributes to errors of reception of second element in 3-element groups; in the date obtained, "most of the errors comes from the third word (element)." No bibliography.

Moser, Henry M., Dreher, John J. **EFFECTS OF CONCURRENT USE OF TWO ALPHABETS**. OSURF Project 51%. Report no. 5. November 1953.

Two groups of U. S. listeners were pre-trained (10 hours), one on US-UK, the other on ICAO alphabets; both were given articulation tests (recorded by US and foreign talkers) in the alphabet of pre-training, at $S/N = -12$ db., then given one hour cross-training in the second alphabet (US-UK in one case, ICAO in the other), and then required to transcribe articulation tests in both alphabets, administered in separate lists. Conclusion: "efficiency of operations would be enhanced by the utilization of a single alphabet".

US-UK-trained group showed improvement of 10% (from 96% to 95.9%) in articulation of foreign talkers during subsequent testing in ICAO.

A second experiment investigated the effect of training in one alphabet (ICAO) and in two alphabets (US-UK) and ICAO) on speed of response in transcribing written messages into voiced productions. No significant difference between groups was found, re: response-time or inhibition to choosing non-alphabet alternate words. No bibliography.

Moser, Henry M., Dreher, John J. NUMBER TELLING AND DIGIT PRONUNCIATION. OSURF Project 519, Report no. 7, February 1954.

Thirty-two listeners were given articulation tests recorded by eight speakers, who spoke lists of two-digit numbers (i.e., 10 to 99) in randomly mixed "group"/"individual" format (group=ninety-nine; individual=nine-nine). S/N = -16, -20 db (white). Listeners were drawn from U. S., English, Filipino, Indian, Japanese, German, Finnish, Spanish, Greek, Czech nationalities; talkers were American, German, British, Spanish, Finnish. Results support conclusions that at both S/N's the "individual" number-telling method provides better reception, regardless of talker and listener nationality.

Second experiment investigated the effect of various pronunciations of digits on reception at S/N = -21 db (white), with eight speakers of Spanish, Greek, Japanese, German, and U. S. origin, and 13 native U. S. listeners. Digits from 0 (zero) to 9, with variants THREE for THREE, FIVE for FIVE, and NINER for NINE included in randomly drawn lists. Results: THREE was significantly better than TREE, there was no significant difference between FIVE and FIVE or NINE and NINER, regardless of national origin of talker. Footnote references to three titles.

Moser, Henry M., Dreher, John J. MONAURAL DELAY. OSURF Project 519, Report no. 9, March 1954.

(Conclusions): using two types of stimulus material (verbal instructions & ICAO alphabet 3 letter number groups) presented aurally via tape-recordings, intelligibility was significantly better* when signal arrival at one ear was delayed. .06 second re: arrival at opposite ear. S/N = -12 db in all data. Presenting delayed signal to right ear yielded significantly ("and materially") better scores in code (letter+number) groups than when same material was presented delayed to left ear.

* As compared to simultaneous presentation to both ears.

Moser, Henry M., Dreher, John J., Patterson, Robert E.
SENTENCE ELEMENTS AND LISTENER RESPONSE.
AFCRC TR 54-80, August 1954.

(From Conclusions):

Use of prefix "please" before instruction yielded no statistically significant improvement of intelligibility.

The following paraphrase expressions were found superior to those in the righthand column

AT ONCE	IMMEDIATELY
OVER	ABOVE
UNDER	BELOW
READ	HEAR etc.

No differences in articulation score can be related to a word's root; Latin and Anglo-Saxon words appear to be equally effective.

The mode of utterance (command, question or statement) does not affect its articulation score.

Commands are as effective without tag words as with them.

Sentence length and articulation score have a low negative correlation.

Moser, Henry M., Dreher, John J., Adler, Sol THREE-DIGIT NUMBER TELLING AND REPETITION METHODS.
AFCRC TR 54-81, August 1954.

From Discussion and Conclusions: PHASE I

Listeners: (1) N = 10 (8 US, 1 Rumania, 1 Jordan)
(2) N = 11 (4 US, 3 Indian, 2 Japanese,
1 Spanish, 1 Jordan)

Talkers: N = 8 (US, German, Greek, Indian, Spanish)

Stimulus material: 24 lists of numbers (3-digit), each presented 3 times in each of three forms: 3-2-4,

3-twenty-four, three hundred twenty-four. S/N = - 12 db

Conclusions: Single-digit method (3-2-4) better than other two where foreign and U. S. talkers/listeners are present.

With US talkers/listeners only, all three are equally effective.

PHASE II: methods of repeating number-telling. Each of above three methods was paired with itself and the other two for repeating transmissions. Repeating 3-2-4 3-2-4 produced no improvement of intelligibility; three-hundred twenty-four-three-twenty-four was best of all tested.

PHASE III: compared single presentation of 3-2-4 and each of three repeat methods.

Found some differences among nationalities, also 3-2-4 singly as good as 3-2-4-3-2-4 repetition, also as good as 3-2-4-3-twenty-four, and as good as three-twenty-four - three-two-four.

Moser, H. M., Dreher, J. J. N-V ALTERNATE WORD INVESTIGATION. AFCRC TR 54-83, (OSURF Project 519, Report no. 13) September 1954.

NOTAM,-NECTAR, VAMPIRE-VICTOR alternates for N and V in ICAO alphabet were selected for intelligibility testing, using talkers of Spanish, Colombian, Italian, French, Thai and U.S. origin. Each alternate was combined with two other letters from ICAO alphabet to form 3-letter groups containing only one N or V word per group. Lists of groups were read to 17 listeners (12 males, 5 females), given 8 hours of pre-test training. S/N = -9, -12 db. Same lists were also presented to a listening panel made up of the original talkers (see above). Results: no significant improvement of NOTAM-VAMPIRE over NECTAR-VICTOR.

Random arrangements of NOVEMBER, NECTAR, NYLON, OSCAR, OZONE, FOXTROT, WHISKEY, VICTOR, ECHO, HOTEL, ROMEO, CHARLIE, X-RAY, read by French, US, Italian, Indian, Jordanian nationals were presented at S/N = -15 db (composition of listener group not described; presumed to be same as before) to determine intelligibility.

Results: US most intelligible, French & Italian second, Jordanian third, Indian least intelligible.

Confusion-matrix analysis showed NECTAR-VICTOR more often confused in certain ICAO alphabet contexts than in others. Recommendations: for (N) NOVEMBER should

replace NECTAR in original ICAO alphabet.

Moser, Henry M., Dreher, John J., Patterson, Robert E.,
Adler, Sol. SENTENCE FORM AND INTELLIGIBILITY (FLIGHT
TRAFFIC INSTRUCTIONS). AF C.R.C. TR 54-85, September 1954

Simulated air traffic control messages for voice R/T transmission were prepared in both "telegraphese" and full-dress formats, presented to 300 native-U.S. listeners by each of 10 speakers representing five nationalities (Spanish, including Uruguay and Ecuador; French, German, British; U.S.), via tape-recording. Messages typified operational communication in 7 phases of flight operation, and presented in customary operational sequence. Recordings were played to listeners at S/N = -5db (white). Listeners wrote down detailed reproductions of messages transmitted by talkers. Scores were percent correct copy rendered by listeners.

Conclusions: (1) No significant difference in reception scores of flight information was observed between full English sentence form and the abbreviated usage demonstrated in the ANC manual (ICAO publication of recommended practices) as practiced by several international towers in the United States. (2) No significant differences were registered by American listeners in respect to Spanish, French, German, British or American speakers under a condition of moderate noise interference.

Reference 1, p 7 of TR 54-85, shows that telegraphese will conserve about 14% of communicating channel time. Authors reason that continued use of telegraphese is adequately defended by findings reported. (Bibliographic footnotes = 4 titles.)

Sample messages in both formats, also listener answer sheets, are included.

Moser, Henry M., Dreher, John J., Adler, Sol. FOUR-DIGIT NUMBER TELLING TESTS. AF C.R.C. TR 54-86, September 1954.

Four types of four-digit number telling were investigated:

- A. single digit (e.g. one-two-three four)
- B. group (twelve thirty-four)
- C. mixed (one, two-thirty-four)
- D. full word (one thousand, two hundred, thirty-four)

American listeners handled all methods equally well when either Americans or foreigners were speaking. Foreign subjects, listening to Americans, did best with the single-digit method, worst with the full-word method. When listening to an international speaker panel, foreign listeners exhibited no differences with methods A, B, C, but again scored lowest with the full-word form.

Moser, Henry M., Dreher, John J. PHONEMIC CONFUSION VECTORS. AFCRC TR 54-84, September 1954.

Test responses of listeners from 27 countries who were tested over a period of a year and a half on several versions of word spelling alphabets are examined to determine patterns of intra-ensemble confusion. On the word level, confusion seems to hinge on the accented vowel, and these confusions are stratified according to the articulatory position of the vowel. Greater discrimination for front vowels than for back is noted, as well as diminishing intra-ensemble confusion from high-to-low articulatory position. A method for computing confusion vectors is presented along with a rationale for increasing the phonemic stability of any particular set of words.

(From Conclusions, TR 54-84, p 14)

2. Of the three categories formulated, Category I (/i/ and /u/) (NOTE: "three" and "two") has most internal confusion, with Category II (/I/ and /U/) and Category III (/e/, /ɛ/, /æ/, /ɔ/, /ɑ/, /ɔ:/) showing increasing stability, notwithstanding their greater theoretical possible chances for error.

4. The confusability of a word or set may be calculated from error frequencies in an articulation test.

5. Larger inter- than intra-category confusion values is evidence of phonemic instability in a set of words.

Moser, Henry M., Dreher, John J., Adler, Sol. TWO-DIGIT NUMBER TRANSMISSION BY VOLUNTARY STUTTERING. AFCRC TR 54-82, September 1954.

Foreign and American listeners heard two-digit numbers transmitted in two different ways: (1) normal delivery (one-two), and (2) voluntary stuttering (wuuh-one-tuh-two). The signals were presented at five

different S/N ratios and the articulation scores were compared for differences (1) at noise levels and (2) between methods.

In both methods American listeners achieved significantly higher articulation scores than foreign listeners at four of the noise levels. Voluntary stuttering gave both groups significantly better results, with score improvement relatively increased as the S/N ratio made listening more difficult.

Stimulus materials: two-digit numbers.

Moser, Henry M., Dreher, John J. A COMPARISON OF THE THREE N-WORD ALTERNATES IN THE MODIFIED ICAO ALPHABET. AFCRC TR 54-88, November 1954.

Twenty-six subjects representing 17 nationalities listened to speakers of 8 nationalities pronouncing random groups of words from the 4-word ICAO alphabet modification, including the alternate words nugget and November.

November proved superior to nugget or nectar.

Moser, Henry M., Dreher, John J. STANDARD PRONUNCIATION OF THE MODIFIED ICAO ALPHABET. AFCRC TR 54-89, December 1954.

Experiment tested most intelligible alternate pronunciations for (A) ALFA = AL-fuh, Ahl-EA; (N) NECTAR = NECK-ter, Neck-TAR; (O) OSCAR = AHs-kar, Aws-KAR; (V) VICTOR = VICK-ter, Vick-TOR; (Q) Quebec = Kay-BECK, KEH-beck; (F) = FOX, FOXTROT. Talkers were 8 male nationals of Brazil, Colombia, Byelorussia, Poland, Germany, Italy, Holland, U.S. Listeners: three groups tested separately - (a) 11 U.S. females; (b) 26 nationals of Argentina, Brazil, Colombia, San Salvadore, Japan, Korea, Turkey, Jugoslavia, Byelorussia, Poland, Austria, Finland, Italy, France, Syria, Iran, Iraq. (c) 75 U.S. males AFROTC students. S/N = -8, -12 db.

Results: (Q) Quebec, recommended pronunciation = Kay-BECK or kwi-BECK; (f) FOXTROT to be maintained. With these exceptions, "any pronunciation of stress on ICAO words within normal phonemic limits of user nations is acceptable for international communications."

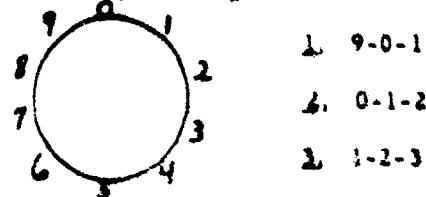
Moser, Henry M., Dreher, John J., Adler, Sol. A COMPARISON OF CIRCLE COUNTING TO THREE METHODS OF REPEAT TRANSMISSION OF THREE DIGIT NUMBERS. AFCRC TR 54-90, December 1954.

Four methods of transmitting three-digit numbers were compared at four S/N ratios.

These methods were:

- 1) Repeat method AC: "468, I say again, four hundred sixty-eight."
- 2) Repeat method CA: "Four hundred sixty eight, I say again 468"
- 3) Repeat method CB: "Four hundred sixty eight, I say again four hundred sixty eight"
- 4) Circle counting: "468, I count, 4, 2-3-4; 6, 4-5-6; 8, 6-7-8."

The latter method, which considers the 10 digits as arranged in a circle, identifies each digit by counting up to it with the 2 preceding.



At all S/N ratios the circle counting proved significantly superior to any of the three repeat methods which were the best of nine possible types of repetition.

Moser, Henry M., Dreher, John J. PRELIMINARY MAYDAY-SOS COMPARISON. AFCRC TN 55-52, February 1955.

Mayday gives listening scores superior to SOS when tested with foreign speakers in heavy noise.

Moser, Henry M., Dreher, John J., Oyer, Herbert J. THE RELATIVE INTELLIGIBILITY OF SPEECH RECORDED SIMULTANEOUSLY AT THE EAR AND MOUTH. AFCRC TN 55-50 February 1955.

Word-lists read by six male talkers were recorded simultaneously at talkers' mouths and left ears. Word-lists were each 50 words, compiled from CAA-control-tower word count of 1951. Each talker read four

scramblings of each list. Recordings were played to a listening panel of 24 trained observers, in three s/n conditions: +6, 0, -6 db. No filtering was interposed; listeners received s+n in PDR-8 headphones (Presumably binaural). Conclusions: mouth signal was superior to ear-signal; however, intelligibility of ear-signal was high enough to deserve consideration as a mode of communication under certain circumstances (not specified.). Notes that positioning ear-transducer affects "the quality of the ear-signal", also that a special ear microphone might be devised to operate on the ear signal more efficiently. (Bibliography of two titles)

Moser, Henry M., Dreher, John J., Oyer, Herbert J. THE RELATIVE INTELLIGIBILITY OF SPEECH RECORDED SIMULTANEOUSLY AT EAR AND MOUTH. AFCRC TN 55-53, March 1955. (Supplementary report no 1).

Indications from the preliminary phase of investigation are followed up herein. Speech signals were recorded simultaneously at the left ears and lips of six adult male speakers. Test materials consisted of 50 monosyllabic words of high frequency in air operations, selected from a sampling of 120 CAA control towers. These words were balanced to approximate closely the vowel and diphthong occurrence in English monosyllables. Each speaker recorded six randomized lists. These lists were presented randomly with respect to origin to a panel of 24 trained listeners in quiet and at five S/N ratios. The criterion measure employed was the total number of correct responses to six speakers for each listener at each S/N ratio considered.

Origin of speech signal, S/N ratio, and listener constituted the three factors in the design. S/N's = -6, -9, -12, -15 and -18 db. Results: In quiet speech picked up at ear was as intelligible as speech picked up at mouth; decreasing S/N is significantly destructive to intelligibility of speech picked up at both ear and mouth, and is more destructive to speech picked up at mouth; at -12 db s/n, ear speech is significantly better than mouth speech; ear signals become relatively more intelligible than mouth signals as s/n decreases; conclusion: "further work on engineering a microphone for the specific nature of the ear signal would be warranted" (Two references).

Moser, Henry M., Dreher, John J., Adler, Sol. EFFECT OF VOCAL INFLECTION ON THE INTELLIGIBILITY OF TWO-UNIT SIGNALS. AFCRC TN 55-54, March 1955.

SUMMARY:

Native American listeners recognize three gross inflection patterns in speaking: rising, level and falling. These three patterns, combined to make nine paired sequences, were applied to four types of two-unit signal: 1. Intoned vowel pairs; 2. Two-digit numbers; 3. ICAO alphabet word pairs; 4. Digit-word pairs.

Responses of trained subjects at -9, -12, and -15 db S/N ratios indicate that: 1. The rank order effectiveness of the nine contour sequences differ somewhat with the type of signal transmitted. 2. Generally speaking, flat-flat (- -) and rising-rising (//) inflections are best with all types of signal transmitted. 3. With all signals there is noted a "mirror image" effect, in which a time-order reversal of contour is consistently damaging to the message (e.g. if rising-rising was good, then falling-falling was worse, and so on with the rest of the sequences). 4. Intensity of a contour is unaffected by its tonal environment.

Moser, Henry M., Dreher, John J., Adler, Sol. THE EFFECTS OF CONTROLLED AFFECTIVE TONE ON INTELLIGIBILITY. AFCRC TN 55-59, June 1955.

Conclusions (paraphrased): "Through the use of stimuli with little associational value, it would appear that the overlay of controlled emotion adds nothing to intelligibility. Thus, for digits, at least, the encoder (talker) may transmit with a certain range of emotion that neither helps nor hinders the auditor (listener)."

It is uncertain what the results would have been if no emotional intensity control had been used. It would seem, subjectively, that anger might have been superior to other modes of transmission."

Emotions represented: Normal, Sadness, Joy, Anger. Inter-talker (three males, one female, all "experienced stage people") variance and inter-emotion variance were both non-significant. Listeners were 39 AFROTC OSU students. Stimulus materials were lists of two-digit numbers. Listeners wrote down numbers immediately following presentation of each pair.

Moser, Henry M. THE EFFECTS OF CONTROLLED BOUNCE BLOCK AND PROLONGED BOUNCE BLOCK ON THE INTELLIGIBILITY OF OPERATIONAL WORDS. AFCRC 55-61, June 1955.

Conclusion:

"....On the basis of the....tests and preceding results (Two-digit Number Transmission by Voluntary Stuttering". Moser, Dreher and Adler, AFCRC 54-82) it is concluded that the bounce block materially aids transmission of the PB monosyllables under unfavorable reception conditions. Under the same conditions the prolonged block method was inferior to both other types of delivery. ("i.e., bounce block and normal).

Oyer, Herbert J. RELATIVE INTELLIGIBILITY OF SPEECH RECORDED SIMULTANEOUSLY AT THE EAR AND MOUTH. OAL Project 519, (No TN no.), July 1955

Monosyllabic words recorded at the lips and left ears of six speakers were fed to the headsets of 24 trained listeners at -12, -15, and -18 (db) S/N ratios. Although the trend for intelligibility scores throughout the test is in the same direction for signals of both origins, decreasing S/N ratio is more destructive to the speech picked up at the lips (5 references)

Moser, Henry M., Dreher, John J., Adler, Sol. A COMPARISON OF HYPONASALITY, HYPERNASALITY, AND NORMAL VOICE QUALITY ON THE INTELLIGIBILITY OF TWO DIGIT NUMBERS. AFCRC TN 55-60, July 1955.

"Six Eastern and General American speakers, using hyponasal, hypernasal and normal voice qualities recorded random lists of two-digit numbers for presentation in noise to 11 trained listeners, all of whom had 32 hours of practice in listening and testing in noise. Results indicated while voice qualities acted in a relatively similar manner at both signal-to-noise ratios tested (-12, -15 db), hypernasality was destructive at the milder noise level, and normal delivery was best throughout."

Moser, Henry M., Dreher, John J. EVALUATION OF THE MILITARY ALPHABETS. Speech Monographs, Vol. 22, no. 5, (November 1955).

Reports intelligibility and preference comparison of US-UK

and ICAO (old) alphabets, and digits including THREE-TREE, FIVE-FIFE, NINE-NINER, ZERO-OH. Subjects: OSU Students, foreign and US; Airmen of US, English, Australian, French, Belgian, German, Greek, Czech, Rumanian, Jordanian, Israeli, Finnish, Swedish, Italian, Colombian, Spanish, Turkish, Chinese, Japanese, Thai, Indian nationalities. Employed S/N of 0, -5, -10, -12, -16 db. Found old ICAO superior to US-UK under all S/N except 0 db ($p = .01$ to $.001$). Also found 9 hours pre-test training time minimum necessary for both alphabets; subjects reported in this study were trained for 12 hours before testing (articulation).

Preference was measured by having S's respond to tachistoscopic display of 3-letter groups by calling off the letters in the alphabet of their choice; result: significantly greater use of ICAO.

Moser, Henry M., Dreher, John J. EFFECTS OF TRAINING ON LISTENERS IN INTELLIGIBILITY STUDIES. JASA vol. 27, no. 6, pp 1213-1219. (November 1955)

Abstract:

Six hundred English monosyllables formed by successive agglutination of initial consonants were presented in high noise to twelve subjects skilled in listening in noise but uninformed as to the words. Alternate training and testing sessions were conducted at weekly intervals following this initial test and differential responses to the words were plotted. Results indicate that correct response is inversely proportional to the number of speech sounds in the monosyllable, with one exception: the two-sound monosyllable is superior to all other lengths when subjects have had even one chance to hear words read aloud. Responses grow progressively better, apparently becoming asymptotic to a ceiling value determined by the S/N ratio, at the same time preserving the same order of difference as established by the naive group.

PB lists now in current use in audiology are analyzed according to phonetic length and a method for correcting internal inconsistencies in lists is proposed.

Amount and kind of listener training is seen as a primary variable in intelligibility testing.

Contract AF 19(604)1577

Moser, Henry M., Dreher, John J., Adler, Sol
POSITION AND WEATHER TELLING METHODS.
AFCRC TN 55-62, July 1955.

AFROTC students at Ohio State were tested to determine effectiveness of three formats for transmitting aircraft position and weather information by voice radio. The formats were: (1) Tag-word (number-groups separated by tag-word identifying the class of data to follow); (2) Plain telling (no tag-word; number groups separated only by distinct pauses); (3) Fast telling (number groups only, read as fast as possible). Messages were recorded by "experienced talker", General American speech habits. Measures of word-rate were taken (Tag-word = 112 wpm, Plain-telling = 74 wpm, Fast-telling = 101 wpm); also duration of individual messages were averaged. Object of measuring rate & message-time was to relate listener-performance (no. correct messages) to communication rate and channel-time, so as to evaluate each format in quasi-operational terms. During listening-tests, S/N = -3db (tape-recorded white noise played thru loud-speakers). Conclusion: "For accuracy, in telling digit encoded weather messages, the plain telling style with definite pauses between message elements was most effective." Also, "some practice in a very fast rate is desirable.....since (if it were to be used).....a greater amount of the message is salvaged by listeners who had previously (been required to transcribe fast-telling messages, as compared with those who had not)." NOTE: listeners were also required to copy messages read in the Fast telling format (see above), at 150 wpm rate, following the experimental listening sessions. (Bibliography of one title.)

Moser, Henry M., Bell, G. E. JOINT US-UK REPORT,
SUMMARY STATEMENT ON NUGGET-NOVEMBER TESTS.
AFCRC TN 55-66, 5 August 1955.

Experiments were designed to determine whether NUGGET or NOVEMBER was the better replacement for NECTAR in original ICAO alphabet (NECTAR found to be highly confusable with VICTOR). Talkers:

in U. S. tests - American, Brazilian, Colombian, Dutch; in UK tests, air traffic controllers (British). Both groups of talkers called out three-letter groups "involving both NUGGET and NOVEMBER" (details unspecified).
Listeners (US tests) total $N = 61$ pilots, air cadets, trained international controllers; $S/N = 0$ db. Results: NOVEMBER superior to NUGGET at $p = .001$. UK test (British controllers), results: NOVEMBER superior to NUGGET, $p = .01$ to $.001$. UK test with 9 trained international controllers @ $S/N = -18$ db in headsets showed no significant result for either NUGGET or NOVEMBER. Recommendation: replace NECTAR with NOVEMBER.

Moser, Henry M., Dreher, John J., Oyer, Herbert J. THE RELATIVE INTENSITY OF SOUND AT VARIOUS ANATOMICAL LOCATIONS ON THE HEAD AND NECK DURING PHONATION OF VOWEL SOUNDS. AFCRC TN 55-70, August 1955.

Measurements of sound intensity during vowel phonation are reported for various transducer positions from the larynx to the top of the head, as a step in locating an optimum location for a voice-communication microphone. Individuals (adult males) were chosen to exemplify three major somatotypes: short-stocky, medium, slender. While each subject intoned vowel sounds, the output of a bone-conduction pickup was tape-recorded; sixteen different zones around the head were sampled; twelve vowels were intoned by each subject at each transducer location. Data are reported as percentages of sound-levels secured at the larynx. A rank-order of intensity is established re: anatomical location of pickup points (no references).

Moser, Henry M., Dreher, John J., O'Neill, John J., Adler, Sol A COMPARISON OF SINGLE- AND DOUBLE-BOUNCE TRANSMISSION UPON THE INTELLIGIBILITY OF OPERATIONAL WORDS. AFCRC 55-69, August 1955.

"On the basis of the....tests and previous results it is concluded that the single-bounce type of delivery leads to a greater word intelligibility than does the double-bounce.

Stimulus materials: PB lists in carrier sentence; talkers: one native U.S. American male, General American speech; listeners six male + four female students, pre-trained with

non-stuttered word lists.

Moser, Henry M., Dreher, John J., Adler, Sol. NUMBER TELLING OF REPEATED DIGITS, EVEN HUNDREDS AND THOUSANDS. AFCRC TN 55-73, October 1955.

Articulatory efficiency of telling grouped numbers was measured, using following formats: (a) 511 = five-double-one or 5111 = five-triple-one vs. five-one-one or five-one-one-one; (b) 225 = double-two-five or 2225 = triple-two-five vs. two-two-five or two-two-two-five; (c) 3446 = three-double-four-six or 34446 = three-triple-four-six vs three-four-four-six or three-four-four-six. With US talker and listeners, no significant differences were found. Second experiment measured articulation of hundreds and thousands in formats of 100 = one-zero-zero vs. one hundred, 1500 = one-five-zero-zero vs. one thousand five hundred, 1000 = one-zero-zero-zero vs. one thousand. Using US talker and listeners only, apparently significant differences were found favoring single-digit format; however, highest articulation scores did not approach 50% correct. S/N = -15 db (white) in all cases. Authors conclude this evidence confirms previous findings. (Bibliography of four titles)

Moser, Henry M., Dreher, John J., Harbold, George J. RECOGNITION OF THREE MAGNITUDES OF INTERPHONEMIC TRANSITIONAL INFLUENCE. AFCRC TN 55-74, December 1955.

This study was done to see if recognition of nonsense syllables could be related to the magnitude of interphonemic transitional influence. Monosyllabic nonsense syllables were structured by combining consonants and vowels, with respect to hub location, to effect three discrete magnitudes of transition, namely, (1) Minimum, (2) Medium, (3) Maximum categories. CV, VC, and CVC syllable forms afforded (a) double representation on of each magnitude by each sound combination within each list of syllables, and (b) equal representation of magnitudes as to location of transition with respect to the vowel. Six male speakers recorded the syllables to which 24 trained listeners responded (syllable and speaker orders randomized) in progressively destructive S/N ratios. The + 3 db S/N ratio results were analyzed.

The criterion measure was magnitude recognition irrespective of transition direction. Data were evaluated by triple analysis of variance. Results supported the hypothesis that magnitudes of transition could be differentially recognized and identified.

Definite superiority of Minimum transitions over the two greater magnitudes was revealed. Transitions preceding the vowels were superior for both the Minimum and Maximum categories, but there was no significant difference between positions for the Medium magnitudes.

It was concluded from the results of this study that (1) transemes, or discrete magnitudes of interphonemic transitional influence, exist as entities and deserve further consideration in future efforts to delineate the code units of speech; (2) magnitude of transition, direction disregarded, does not provide recognition cues; (3) position of transition shift, with respect to the vowel, is significant for certain magnitudes; (4) direction of shift does not contribute to recognition of magnitude; and (5) transition magnitude might be investigated to determine possible involvement in articulation testing.

Moser, Henry M., Dreher, John J., Adler, Sol. EFFECT OF RATE AND PHRASING ON INTELLIGIBILITY OF AIR MESSAGES. AFCRC TN 55-68, May 1956.

Five trained talkers recorded three messages in each of six lists of 13 messages of the following syntactic types: Command, Information, Question, Telegraphese, Word-plus-Prepositional-Phrase, Infinitive-Plus-Object. The controlled variable was rate of speaking delivery: (1) Normal (i. e., habitual), (2) As fast as possible, (3) Paced, with 1/2-second pauses interpolated between phrases, as indicated by a signal. Listeners wrote messages presented via loudspeaker, at S/N = -3db (white noise). (Nature and procedure of listener response not described in report).

"On the basis of overall scores... covering the five message types in this experiment, no statistical difference can be shown between the natural and deliberately spaced methods of presentation.... It is quite clear that the "fast-as-possible" method is prohibitively inaccurate." Conclusion: "On the basis of practical considerations.....the normal rate and phrasing would

appear to be the most desirable type of delivery."
(Bibliography of 18 titles.)

Moser, Henry M., Dreher, John J., Oyler, Herbert J. THE RELATIVE INTELLIGIBILITY OF SPEECH RECORDED SIMULTANEOUSLY AT EAR AND MOUTH. AFCRC TN 55-46, May 1956 (supplementary report no. 2)

Six male speakers read three randomizations of 50 PB monosyllabic ATC words of high frequency selected from sampling transmissions from 120 CAA control towers. This material was recorded against noise backgrounds of 85, 95, and 105 db SPL. AIC-10 microphone M-33/AIC noise-cancelling type was compared with Dyna-Lab D-69 Magnetic Insert Transducer (mounted in talkers' right ear-canal. Both devices were employed for simultaneous recording of talker output.

Articulation-test data were taken by listening panel of 12 trained observers having clinically normal hearing. Listening tests were conducted in quiet.

Results: ear transducer produced superior articulation scores at all three SPL's, with greatest superiority at lowest SPL (85 db). At 105 db, difference between M-33 and D-69 was very small and non-significant. Several explanations are offered; limitations of M-33 are criticized. (two references)

Moser, Henry M., Dreher, John J., Adler, Sol) NUMBER TELLING OF REPEATED DIGITS, EXACT HUNDREDS AND THOUSANDS. AFCRC TN 55-73, June 1956

Phase I compares effectiveness of single-digit telling of multiple numbers in sequence with telling by use of "double" and "triple" designators. Phase II compares telling of each single digit in hundreds and thousand with telling of initial digits followed by "hundred" or "thousand" designators. Speakers and listeners were Eastern-U.S./General American; stimulus materials were presented by tape-recording via headphones; S/N = -15 db (inferred from description of Presentation, page 3). Conclusions: Using "d 'ble" and "triple" to denote multiple successive occurrences of digits does not offer any advantage over single-digit telling; use of "hund-ed" and "thousand" is inferior to single digit telling of numbers involving these magnitudes.

Subjects were required to write down numbers heard through noise. Bibliography of two titles.

Moser, Henry M., Dreher, John J., O'Neill, John, Adler, Sol.
EFFECTS OF REPEATING THE INITIAL SOUNDS OF WORDS ON THE INTELLIGIBILITY OF AIR MESSAGES. AFCRC 55-69, June 1956.

Procedure involved measuring intelligibility of connected speech and isolated words, when spoken with and without stuttering "bounce" at beginning of each word. Conclusion: "intelligibility of air messages might be significantly and importantly increased by the judicious use of the single bounce technique in voice delivery". Recommends further research with operational personnel "specifically trained in using this method".

Moser, Henry M., Dreher, John J. **PRELIMINARY TEST OF AIR DEFENSE COMMAND PROCEDURE WORDS.**
AFCRC TN 56-54.

Purpose: to make preliminary test of certain high-frequency air defense procedure words and some possible alternates when spoken by American, French and Danish speakers to American listeners. Stimulus materials: 6 ADC key words (Track, At. Range, Course, Objects, Speed) + 36 other terms currently in ADC (CONAD 55-1) use or being considered as alternates for terms in use. Lists of these 42 words were recorded by talkers and played to American listeners at S/N (white noise) = 5 db, and at S/N ("voice bubble") = 5 db; also in quiet. Talkers were: 2 General American males; English-speaking French, 1 male and 1 female; English-speaking Spanish, 1 male and 1 female. Listeners were required to write down the words as presented; listener responses were scored for errors.

Conclusions: under quiet receiving conditions, reception of the procedure words was "virtually perfect" no matter by what nationality they were read. Both types of noise (white and voice-babble) "seriously affected reception". White noise at a given S/N ratio is more deleterious to intelligibility of these words than is voice-babble at the same S/N. American speakers were more intelligible (to American listeners) than were the other nationalities, under all conditions. The operational tag-words (Target, At, Range, Course,

Objects, Speed) were received significantly poorer than the other operational terms. (No bibliography).

Moser, Henry M., Dreher, John J., Oyer, Herbert J., O'Neill, John J. **EFFECTS OF SEQUENCE UPON THE RECEPTION OF RELATED AND NONRELATED MESSAGE ELEMENTS.** AFCRC TN 56-55, August 1956.

This study evaluates the effects of word order on the reception of short identification sequences of related and nonrelated elements. Its three phases involved 295 American listeners and five American speakers.

Conclusions:

Phase I (loudness judgments between monosyllables and equally-intense time-ordered reversals):

1. latter element of a pair is heard as louder;
2. this tendency increases when the latter element is more familiar than the former, and decreases when latter element is less familiar;
3. judged loudness difference amounts to 2 db.

Phase II (comparing effects of sequence on free forms of common English spondees and couplets):

1. Listeners, when aurally presented the first half of a spondee, could reproduce the whole word with more success than when presented with only the latter half.
2. Listeners when aurally presented with couplets (two commonly associated free forms) could identify the couplets more successfully on hearing the common (expected) order than when hearing the uncommon (unexpected) order, even though the intelligibility of the free forms themselves was equal.

Phase III: considering syntactically related two-unit call designates and nonsyntactically related three-unit call designates: 1. When both two-unit call sign and modifier ensembles are small, either the call sign or its adjective may come first unless the call-sign has relatively high confusability, in which case habitual English word order of adjective-noun is more effective for identifying the pair; 2. Intelligibility of a sequence of three unrelated words is independent of their order of occurrence; 3. Alerting values of the sequences are equivalent unless the call-sign involved is confusable, in which case the alerting value of its

sequence is diminished.

Moser, Henry M., Dreher, John J., O'Neill, John J.,
Oyer, Herbert J. LISTENER RESPONSE SET TO VARIOUS TEST
FORMS. AFCRC TN 56-59, October 1956.

Purpose of experiment: to see what pattern if any emerged from a series of random guesses or answer selections on several different kinds of blank test forms. (Context of problems: speech reception experiments in which listener responses are indicated by entries on answer sheets.) Test forms investigated: 1. 2-alternative checking test; 2. 7-place multiple-choice checking test; 3. multiple-choice cross-out tests - a. horizontal array, 2 to 14 items, b. vertical array, 2 to 14 items; 4. rating-scale blank, requiring assignment of scale-value numbers from 2 to 14 (ends of scale numbered 1 and 15); rating-scale in which respondent indicates by a cross-out one of 7 positions along a horizontal blank. 15-title bibliography.

Conclusions: 1. First two items of two-alternative (e.g. true-false) showed non-chance response set; remaining items showed chance set only. 2. When digits 1 and 2 are used to indicate choice between two alternatives, digit 1 is used significantly more often than 2. 3. Neither two-nor three-alternative crossout items "were conducive to a chance distribution of selections". 4. Four-, five-, six-, seven-, and eight- alternative crossout items showed a chance distribution of selections, on both horizontal and vertical scale-arrangements. 5. With numerical selection method of scaling, only the seven-point range showed chance distributions; ranges of 5, 6, 8 and up through 14 number-selection points showed distributions of selections displaced toward the high end of the scale. 6. Seven-point range laid out horizontally on a "physical scale" produced a chance distribution of interval selections. 7. The distribution of selections accomplished by the numerical entry method and the cross-out method were significantly different for the two- and three-alternative items, no different for the two methods for items offering four to seven alternatives. 8. Seven-alternative items, with available choices laid out in vertical columns and indicated by checking boxes placed in front of the choices, produced a chance distribution of selections.

Moser, Henry M., Dreher, John J., O'Neill, John J.,
Over, Herbert J. COMPARISON OF MOUTH, EAR, AND
CONTACT MICROPHONES. AFCRC TN 56-58,
October 1956 (Revised January 1958).

A first-order differential noise cancelling microphone (RCA M-33/AIC), and selected ear, throat, and bone transducers were used for comparison studies in various recording and listening conditions. The noise cancelling microphone was used as the control microphone and two simultaneous recordings were made for each of three recording conditions (quiet, 100 db and 111 db noise) for each of the four comparison microphones. The recordings made by trained speakers pronouncing Harvard PB words in quiet and noise were presented to trained listeners in quiet and noise.

Under quiet listening conditions the M-33 microphone was generally superior to the other microphones, although the performance of the ear transducer and the bone conduction oscillator was similar to that of the M-33 under quiet recording conditions.

The results under noise listening conditions were more tenuous but they indicated that the ear transducer was superior under all three recording conditions with one of the throat microphones equalling its performance under the two noise recording conditions. A variation of the noise-cancelling microphone mounted in an oxygen mask was compared to the ear transducer and the results were similar to those obtained in the M-33 comparison study.

A second experimental study utilized an improved form of the ear transducer and the M-33 microphone. Recording and listening conditions were somewhat similar to those employed in the first study. Under quiet listening conditions the performance of the M-33 microphone excelled or equalled that of the ear transducer. In ambient room noise listening conditions, performance of the M-33 was clearly superior. Under conditions of in-line noise (i.e., apparently noise introduced electrically across the line between transducer and output) the ear-transducer was superior or equal to the M-33 for two of the three recording conditions. However, the M-33 was superior to the 115 db noise recording conditions (not clear whether this refers to ambient acoustical noise in the environ-

ment surrounding the microphone; if so, this demonstrates the effectiveness of the noise-cancelling feature.) (Bibliography of 16 titles)

Moser, Henry M., Dreher, John J. OPERATIONAL TESTS OF MINIATURE MICROPHONES AND RECEIVERS.
AFCRC TN 56-57, October 1956.

"The primary aim of the operational test was to compare the efficiencies of the currently-used M-33 microphone with selected ear insert and bone transducer in conjunction with the AIC-10 communication system." Substitutions for standard AIC-10 headset were sought to relieve problems of weight, discomfort and sanitation encountered in hot-weather flight-training operations.

Proposed substitute units for AIC-10 (M-33) microphone were used aboard KC-97 and C-124 aircraft. Pilots read PB lists over air-ground UHF radio, were tape-recorded at ground station. Tapes were played back to listening panel in the laboratory. (Note: pilots also read typical "operational messages" in addition to PB lists.) M-33 microphone produced statistically superior results under all test conditions, as compared with experimental types (Dyna-Empire magnetic insert microphone model D-314 and Dyna-Empire bone-conduction model B-36 pickup, positioned respectively in the ear-canals and on the skull). PB's were played to listening panel in quiet and with injected noise additional to that on the tape; only results from in-quiet listening are reported. Listeners N = 10, trained for 30 hours on PB lists, prior to tests.

Second experiment investigated substitution of receivers for standard AIC-10 headset for hot-weather use. This headset and three magnetic ear-canal inserts (same as used in microphone study) were compared by flight team in SA-15 aircraft. No articulation data were taken; judgments of flight personnel favored lightweight units on basis of greater comfort with no loss in communication.

Conclusions: substitution of lightweight ear-microphone/receiver for AIC-10 is considered feasible from articulation point of view, and advan-

tageous from hygienic necessity. Work is in progress to utilize one ear-canal transducer for both transmitting and receiving, without ear cushions or other sound-proofing to attenuate noise. (Bibliography of 5 titles)

Moser, Henry M., Dreher, John J., Wolfe, Susan M.
CONTRIBUTION OF STANDARD SEQUENCE TO AN AIR DEFENSE TASK. AFCRC TN 56-73, January 1957

Typical Air Defense surveillance messages were read with elements in standard order and in random order to two groups of listeners. Each group practiced logging data in one particular type of sequence for seven hour-long training periods at which time the standard and random orders were interchanged to assess the performance of listeners on an unfamiliar type of presentation. A final proficiency test consisting of extremely rapid telling of messages in regular order was administered to both groups to evaluate the two types of training.

Results indicated:

1. When using standard vocabulary and one type of message, the message items may be presented in different sequence to trained groups without seriously affecting reception.
2. Initial results produced better intelligibility scores for the standard-ordered material. However, training appeared to negate this original advantage.
3. Groups trained in standard and random sequence, respectively, showed no significant difference when the presentation method was interchanged.
4. Groups trained in standard and random sequence, respectively, showed no significant difference when subjected to speed tests of standard-ordered messages.

Moser, Henry M., Dreher, John J., O'Neill, John J. **THE MASKING OF ENGLISH WORDS BY PROLONGED VOWEL SOUNDS.** AFCRC 56-74, May 1957.

One hundred and ten monosyllabic words selected from the Thorndike list of 1000 most frequently occurring words in English to represent equally each of the 10 vowels were presented to 300 American listeners in an articulation test. Also treated were 72 spondees.

words, half selected from those in use in audiological tests and half from those in frequent use in air traffic control, further to represent the same vowel sounds. Masking of the stimuli was accomplished by separately recording each of nine prolonged vowels intoned by a trio of male voices.

Results indicate that vowels of equal sound pressure levels differ considerably in masking effectiveness, that words containing a specific vowel are not masked optimally by the same vowel, and that spondees are masked by prolonged vowels in the same rank order as the monosyllables.

Prolonged vowel sounds with relatively high concentration of energy between 700 and 1000 cps are most effective as masking agents.

Rank order correlation of observed masking effectiveness with masking effectiveness predicted by the Strassberg method is .52, the Heronek method is .59, and by the Pickett-Kryter method is .69.

Some observations on resistance of words to masking are made in relation to phonemic transition areas within words.

Moser, Henry M., Dreher, John J., Oyer, Herbert J. ONE-SYLLABLE WORDS. AFRCR TN 55-56, June 1957.

Lists the monosyllabic words of the English language, excepting family names and names of race-horses. Words have been tabulated alphabetically according to vowel sound, with initial and terminal consonants set apart.

Words which may be pronounced as if containing two syllables, although spelled in one syllable, are specially identified.

Words with two pronunciations (dialectic variants) are specially identified.

Words which are entered twice due to final sound of R and/or initial sound of Y are identified.

Number-words are listed only where pertinent to

pronunciation problems.

Homophones (same pronunciations of different spellings) are listed but not always duplicated in plural or variant verb forms. Certain homophonous ending-sound (e.g., -NS, -NTS, -NZ, NDZ) are listed as differentiated.

Socially unacceptable, exotic dialectical, and obsolete words and/or pronunciations are omitted.

Moser, Henry M., Dreher, John J., Schwartzkopf, Lewis J.
AN EAR-MOUTH VOICE TRANSDUCER. AFCRC TN 57-54,
July 1957.

An ear-mouth voice transducer has been experimentally fabricated. The device operates with sufficiently good signal-to-noise ratio to be used without circumaural protection in the noise fields generated operationally by present Air Force propeller-driven aircraft. A small magnetic insert transducer coupled to a custom-fitted earmold, a short length of aluminum tubing, and a small plastic receptacle forming an acoustic link with mouth-emitted speech operates both as a microphone and as a receiver.

Spectral measurements of selected vowels and consonants are presented, along with pickup characteristics of ambient white noise.

Articulation results with Harvard PB words and trained laboratory listeners show that words recorded in 90 db of ambient white noise are identified equally well with the Air Force M/33-AIC and experimental microphones fabricated by this laboratory. The comparatively small margin of difference between the two at levels of 100 and 106 db indicates that they might be operationally equivalent. Sentences recorded in 115 db of engine noise resulted in almost perfect scores with both the M-33 and the ear-mouth device.

Both civilian and military flight operations carried on with the experimental microphone-receivers resulted in satisfactory communications. A summary of opinions by chief instructor pilots at the West Palm Beach (MATS) AFB is presented.

Also recorded are some suggestions for possible improvement of the device for future development.
(Bibliography of 6 titles)

Moser, Henry M., Dreher, John J., Schwartzkopf, Lewis J.
PHRASEOLOGY OF INTERNATIONAL LANGUAGE OF THE AIR.
AFCRC TN 57-51, August 1957.

Implications of the International Civil Aviation Organization State Letter AN 7/38-514 in regard to changes in currently authorized radiotelephone procedures are discussed. A method of testing comprehension of air messages is described, and the results for foreign and American listeners are reported along with comment of a seminar composed of foreign pilots and language instructors of the Air Force Language School.

Tests indicated that the recommended full-sentence forms and the present structures in use are equivalent for conveying the meaning of air messages to both American and foreign airmen.

The concensus of the seminar indicated a definite preference for the brevity and clarity of the presently authorized telephese structures, and opposition to the addition of words and expansion of sentence structures.

Specific suggestions on the choice of words and the sentence structures are included (Bibliography of 4 titles.)

Moser, Henry M., Dreher, John J., Oyer, Herbert J.,
O'Neill, John J., Schwartzkopf, Lewis. **EXPECTATION IN MESSAGE RECEPTION.** AFCRC TN 57-55, October 1957.

Listening panels of foreign and American airmen were given printed lists of monosyllabic words, polysyllabic words, and air traffic instructions. Their task was to decide whether these printed messages agreed or disagreed from correspondingly numbered aural messages which were presented in noise ($S/N = -2$ db). Results indicated that under good listening conditions, both foreign and American listeners were influenced by suggestion regarding the probable amount of message agreement and

disagreement. Listeners could err by (1) failing to identify matching signals, and (2) failing to discriminate between disagreeing signals. In all conditions of exception it was more difficult for subjects to determine when the messages were dissimilar. Magnitude of both error types tended to increase the length of the message; sentences were more subject to error than polysyllabic words, and polysyllables more than monosyllables. Apparently the criteria of listener judgment shifted when the subject was concerned with different lengths of message. Foreign airmen, although more experienced in listening to radio-telephone messages, showed more errors in each type of test material. American airmen, although less experienced in listening to radio-telephone messages showed fewer errors in each type of material than foreign airmen, suggesting the effect of second language influence. Foreign students (airmen) considered to be advanced in English proficiency were more accurate in discrimination and identification than those classed as having only basic proficiency in English.

Moser, Henry M., Dreher, John J. LETTER-DIGIT INTERACTION.. OSURF Project 529, Report no. 8, February 1958.

From Conclusions:

Modified ICAO alphabet when tested with both the standard and special digit pronunciation (1 = TREE, 9 = NINER, 5 = FIFE) performs almost as well as when tested alone.

ZERO has higher articulation value and lower confusability than OH, in the spoken digit system tested.

THREE and FIVE are superior to TREE and FIFE; NINE and NINER are equally effective. Most serious digit confusions involve 2, 3, and 6.

Moser, Henry M., Kirkconnell, Thomas W., Wolfe, Susan M. AN INTERIM REPORT ON INTERNATIONAL LANGUAGE FOR AVIATION. AFCRC TN 57-63, April 1958.

An earlier version of this material was prepared to defend the U.S. point of view that existing

telephrases procedures should be simplified, condensed, and incorporated into a minimum morphological and syntactical base. That version was circulated among members of the ICAO Radiotelephony Speech Panel and had some influence in the decision to recommend the phraseology over that of full sentences.

The material in the present report, which incorporates suggestions made by the Speech Panel, has been revised to present a logical base for the standardization of present and future ILA. The aim has been to discover the fundamental principles used in radio-telephone communication, and to establish rules which will facilitate teaching and which can be followed to formulate phraseologies that have not yet been determined. In short, it proposes rules for an International Language for Aviation.

It is hoped that this report will be studied carefully, and that constructive criticism will be made by those vitally concerned so that the final ILA will be acceptable to American pilots and ground-station operators. (Bibliography of 5 titles)

Table on Page 9 compares U.K. Complete Sentence R/T Procedures with ILA Telephrases.

Moser, Henry M., Oyer, Herbert J., Wolfe, Susan M.
THE RELATIONSHIP OF PHONETIC STRUCTURE TO THE INTELLIGIBILITY OF WORDS SIMULTANEOUSLY RECORDED AT EAR AND LIPS. AFRC TN 78-94, April 1958.

Previous study has shown that when speech signals were recorded at lips and left ears of speakers, and fed to headsets of trained listeners at specified S/N ratios, signals, origin ear, were significantly more intelligible than signals, origin lips. A comparative analysis is made of phonetic elements of listener response to speech signals, origins ear and lips, elicited in the earlier study. Listener responses totaled 72,000. Listeners highly trained on fifty words tend to restrict substitute responses to words within the list for signals of both origins. Fewer substitutions of words from outside the original list occur as

noise in the listening condition becomes more destructive. Substitutions remain relatively constant between origins through S/N ratios. Omissions for stimuli, origin lips, increase more rapidly. Number of sounds in the test stimuli had no differential effect on intelligibility when related to origin. The frequency of occurrence of two, three, four and five sound word substitutes is in almost complete agreement with frequency of occurrence of two, three, four and five sound words in the test list.

Analysis of intelligibility errors relative to vowels and diphthongs in the test list revealed that words containing [æ, ʌ, ɔ, ɒ, ʊ, ʌɪ] were less intelligible from origin ear, than origin lips through S/N ratios. (Bibliography of 15 titles)

Moser, Henry M., O'Neill, John, Adler, Sol. NUMBER TELLING METHODS. AFCRC TR 58-55, July 1958.

Methods of telling one-, two-, three-, and four digit numbers were tested with American and foreign speakers, and American listeners. Speakers were equally distributed male and female representatives of the major American dialects, and foreign nationals of English, French and Spanish origin.

When Americans transmitted to Americans during adverse listening conditions, the following single digit pronunciations were statistically superior:
(0) ZE-RO, (1) UH-WUN, (3) TH-R-EE, (6) SIX-SIXER, SUH-SIX, and (7) SEV-VEN. Those pronunciations which showed no difference were (2) too, uh-hoo, tub-too, (4) four, fo-wer, fuh-four, (5) fi-i-iv, five, (8) ait, a-alt, aiter, and (9) nine, ni-yen, nyner, nuh-nine.

When foreign speakers transmitted to Americans during adverse conditions (listening) the following single digit pronunciations were statistically superior: (0) ze-ro, zero, (2) too, uh-too, (4) four, (5) fi-i-iv, five, (6) six, sixer, (8) ait, a-alt. All other pronunciations showed no differences.

When transmitting two-, three-, or four-digit numbers, all speakers were more intelligible with

the single-digit telling method. This method was statistically superior for every phase of the study with the exception of two-digit number telling in the American-American communication set.

Moser, Henry M., O'Neill, John J., Wolfe, Susan M. TESTS OF THE AURAL COMPREHENSION OF ENGLISH BY FOREIGN STUDENTS. AFCRC TR 56-57, August 1958.

Parts of two tests of Aural Comprehension of English for foreign students were administered to forty-four foreign students representing 25 nationalities and varying backgrounds in English. All of the students were post graduates. The tests used were The Lado Test of Aural Comprehension, Form C, and The MDAP English Proficiency Examination, Form B. Thirty orally-presented items were given from the MDAP test and 60 from the Lado Test.

The data were analyzed in terms of the differences between mean scores (t test) and a product-moment correlation (r). The results of the t test indicated significant differences between the two tests. This might be accounted for by the differences in numbers of items presented on each test as well as the difference in performance levels for each test as established by native speakers of English. The statistical evaluation of r indicated that there was a significant relationship between scores on the two tests.

The MDAP test deals more extensively with military vocabulary than does the Lado but they are both capable of evaluating the aural comprehension of foreign nationals. The Lado test is less time-consuming and would probably be preferred when technical language evaluation is not important.

Nationalities tested: Chile, China, Colombia, Czechoslovakia, Ecuador, France, Germany, Greece, Lebanon, Mexico, Pakistan, Peru, Puerto Rico, Spain, Thailand, Turkey, Guatemala, India, Indonesia, Iraq, Japan, Jordan, Korea, Latvia, Iran.

$t = 8.02 @ df = 42; r_{LM} = .548$, significant @ .01 level for both

Moser, Henry M., O'Neill, John J., Oyer, Herbert J.,
Wolfe, Susan M., Abernathy, Edward A.,
Schow, Ben M., Jr. HAND SIGNALS: FINGER-SPELLING.
AFCRC TR 58-56, August 1958.

This study examines the possibilities of using the finger-spelling alphabet of the deaf as a supplementary medium of communication in high level noise and/or other situations where voice communications are not desirable or effective. A history of finger-spelling is included.

Twenty-four deaf students were used as subjects for the intelligibility testing of nonmeaningful alphabet triples under conditions of artificial lighting and natural lighting. The two senders were very familiar with the finger-spelling alphabet and known by the subjects.

Results indicated that distance between the sender and the receivers or observers was the prime factor affecting intelligibility. At 125 feet, the greatest distance tested with the entire group, the average intelligibility was 87.6%. This led to subsequent testing with 10 selected "better" readers at more extreme distances both under artificial lighting conditions and outdoor testing. At 253 feet, the five best observers still performed at better than 50%. Outdoors the average per cent intelligibility was higher than for the corresponding distance indoors and the average intelligibility was above 50% at 300 feet.

Under all conditions of testing there were tendencies for certain letters to receive more substitutions and other letters to be highly confused with a wide variety of letters.

In general, the intelligibility of alphabet letters was high enough at such distances as 175 feet to indicate possibilities of using the finger-spelling alphabet as a means of supplementing or clarifying present hand signals now in use.

Moser, Henry M., O'Neill, John J., Oyer, Herbert J.,
Wolfe, Susan M., Schowen, Ben M., Jr. A SURVEY OF
FLIGHT-LINE HAND SIGNALS. AFCRC TN 58-57,
September 1958.

SUMMARY:

This report is essentially a collection and preliminary survey of hand signals used by flight line personnel. Two Air Force publications were used as pictorial and descriptive sources and visits were made to an Air Force Base, a Naval (air) station, and an aircraft factory. Photographs were taken of hand signals previously represented in publications by drawings. Modifications of these signs, new signs, and variations on the signs by a deaf man are also shown in photographs.

Recommendations are made for further surveys and a pocket manual of photographed signs (also recommends training film).

Moser, Henry M. STUDY OF RADIOTELEPHONE VOICE PROCEDURES AND RELATED RESEARCH.
AFCRC TR 58-51, 30 September 1958.

Summarizes activity and findings for period 1 December 1955 to 30 September 1958. Lists 13 members of staff employed for varying periods during this time, 21 reports of research (with abstracts of each). Outlines projected plans for future research indicated by military interests in four subject-areas (ear speech, development of training procedures, training aids for teaching hand-signals, pre- and post-stimulation of foreign IIA users).

Contract AF19(604)4575

Moser, Henry M. THE EVOLUTION AND RATIONALE
OF THE ICAO WORD SPELLING ALPHABET.
AFCRC TN 59-54, July 1959.

The development of the word-spelling alphabet is traced, and research methods and findings which led to the recommendation of the ICAO alphabet as an optimum list for international communications are summarized. Questions regarding the desirability and efficiency of the new alphabet are discussed, with the view to presenting what the alphabet intends to accomplish. Some two hundred (200) word alphabets of the world are appended.

Moser, Henry M., Oyer, Herbert J., Fotheringham, Wallace C., O'Neill, John J., Wolfe, Susan M. THE EFFECT OF AUDITORY STIMULATION ON THE PRONUNCIATION OF ENGLISH WORDS BY NON-NATIVE SPEAKERS. AFCRC TN 59-56, September 1959.

Pronunciation of English words by foreign nationals before and after auditory stimulation was rated by experienced judges and tests for intelligibility with panels of native American listeners. In general, auditory stimulation substantially improved pronunciation and intelligibility; it therefore appears to warrant further study as a means for improving communication among many-language groups. Nationalities of speakers: Chinese, French, Guamanian, Indian, Japanese, Polish, Russian, Slovakian. Intelligibility-rating judges N = 2; 1 speaker of each nationality; intelligibility-test listener panels N = 15 to 30.

Intelligibility rating scale: 1. not intelligible;
2. difficult to follow in conversation (recognizable through familiarity but doubtful of recognition alone);
3. intelligible but some distortion; 4. highly intelligible - no distortion.

Moser, Henry M., Dunham, Robert E., AN EXAMINATION OF THE SPOKEN VOCABULARY USED IN AIR TRAFFIC CONTROL. AFCRC TN 59-73, November 1959.

Word counts were made of air traffic communications at three domestic and two international airports

located in high-traffic areas in the United States. Consecutive segments of two-way radiotelephone messages were analyzed for type-token ratios. Pilots and controllers use a very limited basic vocabulary. Although there are similarities in the vocabularies employed in Tower, Ground Control, and Approach Control, there are characteristic differences. In general, there are more differences between the several control facilities of one airport than among the vocabularies of the same control facility at different airports (Bibliography of 13 titles).

Note: from conclusions, cardinal numbers comprise 18.6% of ATC vocabulary (spoken). For Approach Control, numbers comprise 22.5%; Ground Control, 11.4%; Tower Control (also designated Airport Control, 6.7%. TTR's and decremental TTR's (over successive 500 - and 100 word samples) were found.

Moser, Henry M., Oyer, Herbert J., Fotheringham, Wallace C.
ORTHOGRAPHIC REPRESENTATIONS OF THE ENGLISH
PRONUNCIATION AS AN AID IN TEACHING ILA.
AFCRC TN 59-75, December 1959.

Specially devised orthographies in Chinese, Dutch, French, German, Italian, Japanese, Korean, Spanish and Thai were constructed for a list of common English aviation words as an aid to their pronunciation by foreign nationals. Those prepared for German, Japanese, and Spanish were employed with native speakers of these three languages at the A. F. Language School, Lackland AFB, Texas. It was found that for each of these three groups, the specially designed orthographies, with or without the additional aid of auditory stimulation, resulted in significantly more intelligible pronunciations than the reading of these aviation words from only a printed list. Additionally, each individual speaker in this study improved the intelligibility of his pronunciations when aided by the appropriate orthography. The comparative value of orthography alone vs. orthography plus auditory stimulation varies considerably among language groups. The average improvement would make a distinguishable difference in the air traffic communication setting. 500 words (aviation R/T) 25 phrases (ATC). Supplement (no. 1) dated November 1961 (AF19(604)-6179) adds Greek orthography of same material; no test data.

Contract AF19(604)6179

Moser, Henry M., Oyer, Herbert J.,
Fotheringham, Wallace C., Henderham, Robert C. VOWEL
DISCRIMINATION AMONG FOREIGN NATIONALS.
AFCCDD TN 60-39, September 1960.

Test of ability to discriminate between vowels spoken by General American native speakers (N=4), responding by S for same, D for different, was tape-recorded and presented to 133 S's representing Italian, Iranian, German, Vietnamese, Japanese, Spanish language groups and 176 Native U.S., S's. Conclusions: (1) Use of vowel-discrimination test is advisable in assessing the competence of foreign-background students of English and indicating needs for special instruction; (2) improvement in English-language competence can be expedited for foreign-language natives by intensive instruction in phonetics, along lines revealed by response-patterns obtained in this study; it is hypothesized that such instruction would (a) significantly increase familiarity with word patterns, and (b) break down previous ambiguities in English vowel discrimination associated with the native foreign language. It is recommended that such a test as used for this study be used in successive administrations to diagnose particular vowel-discrimination troubles, and as a measure of progress in acquiring English.

Moser, Henry M. ONE-SYLLABLE WORDS, REVISED AND ARRANGED BY ENDING SOUNDS. AFCCDD TN 60-58, November 1960.

Revision and extension of AFCRC TN 55-56.
First paragraph of Introduction:

"This report presents a systematic listing of the monosyllabic words in American English according to their ending sound. It represents a complete revision of One-Syllable Words, AFCRC TN 55-56, in that all words have been re-examined, errors have been corrected, a few words have been deleted, and a number of new words have been added. The summary charts have been revised, and charts of the beginning and ending sounds with the individual vowels and diphthongs have been added. Some changes have

been made in the section on Inclusions, Exclusions and Qualifications. For the most part, the two reports supplement each other; the earlier report presents an arrangement according to the beginning consonant sounds, the present work according to ending sounds."

Moser, Henry M., Fotheringham, Wallace C. NUMBER TELLING. AFCCDD TN 60-40, December 1960.

Intelligibility and confusability values of 16 variants of the English digits were studied in sufficient noise to produce about 50 per cent error. Ten speakers representing five different native-language backgrounds spoke the English digit variants to approximately 250 American listeners. The study provided 21,549 responses to each digit; about half of these were responses to stimuli which had been filtered above 2800 cps.

Results reveal a quite stable order of digit intelligibility which was 5, 1, 7, 0, 6, 4, 9, 8, 1, and 3. Of the variants, THREE and FREE were equally intelligible and significantly better than ZERO, FOWER, FIFE, AND NINer, respectively. FIFE was somewhat superior to FIVE for speakers whose native-language was Spanish. The difference between filtered and unfiltered signals was statistically significant but hardly of practical importance. The digits (3) and (0) were the most frequent substitutions for other digits; (5) and (9) were the least frequently confused. At least one significant confusion exists for each of the digits. No digit avoids being a significant confusion for at least one other digit. Variants of the same digit tend to be associated with the same confusion (Bibliography - 5 titles)

Newman, Anthony K. A LABORATORY STANDARD SIGNAL-TO-NOISE EQUALIZER. AFCCDD TN 60-59, December 1960.

An electronic instrument for establishing and maintaining speech-to-noise relationships for auditory research is described, with detailed instructions for constructing, calibrating and using. Five circuit diagrams, three photographs. (No bibliography).

Moser, Henry M., Michel, John F., Fotheringham, Wallace C.
INTELLIGIBILITY AND CONFUSABILITY OF VOWELS AND
DIPHTHONGS UNDER VARIOUS CONDITIONS OF QUIET AND NOISE.
AFCCDD TN 61-33, March 1961.

Sixteen common vowels and vowel-diphthongs of English (HE, HIT, HAY, HECK, HAT, HOT, HAWK, HUT, HER, HOE, HOOK, WHO, HIGH, HOW, HOIST, HUE) were recorded by four male, four female speakers of General American dialect background. Each speaker recorded five randomly-arranged lists of the 16 sounds, totaling 80 sounds per speaker. Resulting tapes were played over earphones to a panel of six phonetically trained (graduate-student) listeners, under five S/N conditions: noise-free, -10 db, -6 db, -1 db, +2 db, +6 db. Listeners were required to identify sounds in written symbol form. Data were analyzed to determine: (1) differences in intelligibility of isolated vowels and diphthongs at low intensities and relatively difficult S/N ratios; (2) rank-order of vowels and diphthongs re: intelligibility in quiet and in noise; (3) stability of intelligibility rank-order as function of successive increase in stimulus intensity; (4) effect of talker variance on stability of intelligibility rank-order; (5) effect of talker sex on same; (6) vowel and diphthong confusions under quiet and noise; (7) reversability or reciprocity of confusions.
(Bibliography = 17 titles)

Moser, H. M., Fotheringham, Wallace C., and Henderhahn, Robert C. SINGLE-VOWEL INTELLIGIBILITY TESTS. AFESD TN 61-39, March 1961.

Two studies are reported in which lists of words and syllables, each constructed around a single vowel, were compared with PB word lists.

In the first study, three speakers recorded the four W-22 PB lists and eight different single-vowel lists which were phonetically balanced according to the distribution of consonants in English monosyllables (VPB lists). Three hundred fifty-eight (358) Army ROTC students listened to representative PB and VPB lists in white noise. It was found that (1) VPB lists are more representative in respect to syllabic types of English monosyllables, (2) VPB lists differ significantly in intelligibility, and (3) VPB lists are more difficult, and are more effective in indicating differences in

intelligibility between speakers, than the W-22 lists.

In the second study, 40 air-traffic controllers were tested with (a) an expanded single-vowel word list composed of different beginning and ending consonants and consonantal combinations present in English, (b) syllabic lists derived from word-halves of the same vowel list, and (c) Harvard PB list. The word and syllabic lists were transcribed by a phonetically trained panel at S/N ratios of + 15 and + 18 db respectively. It was found that (1) the expanded single-vowel list is much more difficult than the PB list, (2) syllabic lists are reasonably accurate predictors of consonantal errors in words of which they are a part, and (3) syllabic lists and the PB lists are not highly related as indices of intelligibility. Furthermore, the syllabic lists appear to provide an instrument of tremendous potential for diagnostic testing and training purposes. (Bibliography = 7 titles. Introduction suggests possible applications: testing communication eqpt., speaker intelligibility, auditory discrimination of listeners, transmission efficiency of (complete) communication systems. Might also use monosyllables with different beginning & ending consonants to test intelligibility and/or auditory discrimination of foreign nationals (non-English speaking). Might be useful tool in examining phonemic distortions due to foreign-language accents imposed on English, for both research and diagnostic purposes.

Moser, Henry and Leon, Pierre. THE RECOGNITION OF FRENCH VOWELS BY AMERICAN LISTENERS. AFCCDE TN 61-42, April 1961.

The effect of a French accent on the intelligibility of English one-syllable words was studied to predict probable error in voice communication from French speakers to American listeners.

It was found that (1) French sounds cannot be presumed to be equivalent to those of English, (2) certain errors can be predicted when the French phonetic pattern is substituted for English, (3) single vowels are less intelligible than diphthongs pronounced as separate sounds, and (4) special care must be taken in teaching the English vowels [ɒ], [ə], [ʌ], [ʊ], [ʌ], and [i] to speakers whose native tongue is French (Seven references).

Moser, Henry M., Gardner, Harvey J. INFLUENCE OF CONSONANTS ON THE RECOGNITION OF THE VOWELS [u] AND [i] - A STUDY OF INTERNATIONAL PRONUNCIATION FOR TWO AND THREE. AFESD TN 61-38, May 1961.

Thirty native speakers of five different language groups recorded 178 CV and VC stimuli containing the vowels [u] and [i]. Ten Americans listened to different randomizations of the stimuli at three signal-to-noise ratios. The data were analyzed for generalizations regarding consonantal characteristics that contribute significantly to recognition of the vowels [u] and [i] with a view to selecting the most recognizable pronunciations for the digits TWO and THREE.

Five experimental questions tested by analysis of variance revealed:

1. Consonants differ in their influence on recognition of the adjacent vowel; however, these differences vary with each combined effect of the vowel, stimulus form, and language group.
2. The effect of recognizability of consonants on recognition of the vowel depends upon the particular vowel, stimulus form, and language group. Consonants of high recognizability tend to be associated with lower error scores for [i]; an opposite but less consistent tendency is observed in the [u] data
3. Single consonants do not differ significantly from consonantal combinations for most combinations of vowel, stimulus form and language group.
4. The effect of consonantal position is non-significant.
5. The effect of consonantal voicing tends to be significant for [u] and non-significant for [i]. Lower error scores for [u] are associated with voiceless consonants for each language group except Latin-American Spanish. An opposite but non-significant tendency appears for [i].

The conclusions suggest that the intelligibility of TWO and THREE can be improved by the substitution of more recognizable consonants. Bibliography=three titles.

Moser, Henry M., Fotheringham, Wallace C.,
Gonzalez, Guillermo A. AN ANALYSIS OF THE PURPOSES OF AIR-TRAFFIC CONTROL MESSAGES. AFESD TN 61-40, May 1961.

A sample of 8,861 air traffic control messages from Idlewild, Miami, Mexico City, and Accra (Ghana) air-traffic control facilities were transcribed from tapes. From an analysis of communication context, the purposes of the messages were inferred and categorized. Of this larger sample, representative subsamples from each facility, totaling 873 messages, were selected for further analysis of message length and origin.

The findings support the following conclusions:

1. The dominant message purposes of air traffic controllers involve regulation, control, instruction, and advice; pilot messages emphasize acknowledgment, confirmation, request, and provision of nondirective information.
2. Air-traffic controller messages are significantly longer and occur less frequently in R/T communication than pilot messages.
3. Air-traffic controller messages are about equal in message length, while pilot messages vary and are shortest in airport control communication.
4. American facilities employ a greater proportion of messages concerned with aircraft position, while foreign (i.e., non-U.S.) facilities employ a greater proportion of readbacks and acknowledgments.
5. Air-traffic controller messages are significantly longer in foreign facilities than in American facilities.
6. Nonroutine and negative statements, and requests for message repetition occur quite infrequently at all facilities sampled. (Three references).

Moser, Henry M., Fotheringham, Wallace C.,
Gonzalez, Guillermo A. VARIANCE IN THE RATE OF SPEAKING BY PILOTS AND CONTROLLERS IN COMMUNICATING TO U.S. AND FOREIGN LISTENERS. AFESD TN 61-41, August 1961.

"It was the purpose of this study to examine recordings

of speakers - pilots and controllers - both at foreign and domestic air traffic facilities, to determine if adjustments are made in terms of perceived listener needs" in air-ground ATC voice radio communication. Tapes from Idlewild (5824 messages), Miami (1035 messages), Mexico City (587 messages) and Accra, Ghana (1416 messages) were transcribed, and analyzed for rate of utterance. Findings support conclusions: (1) pilots & controllers at international ATC facilities use slower rates (statistically significant) when speaking in English to pilots or controllers whose native language is not English; (2) Pilots & controllers vary in the extent to which they will employ slower rates for listeners not native to English. "Pilots & controllers adjust rate.... to match perceived listener needs." (No refs.)

Moser, Henry M., Fotheringham, Wallace C. INTELLIGIBILITY OF BEGINNING AND ENDING CONSONANTS WITH THE VOWEL /I/. AFESD TN 61-37, December 1961.

Consonants and consonant clusters with the vowel /I/ were formed into CV and VC stimuli and were spoken by male and female speakers in flat noise to phonetically trained listeners.

The study provided the bases for the following conclusions:

1. The order of intelligibility varies with speakers but is significantly more stable for initial consonants and for speakers of the same sex.
2. Final consonants are more intelligible than initial consonants.
3. Confusions among initial and final consonants are similar with place of articulation, the most difficult articulatory feature to distinguish.
4. Consonant clusters tend to be less intelligible and confusions are related to their component sounds.
5. CVC units formed from the more intelligible CV and VC syllables are significantly more intelligible than units formed from the least intelligible syllables. (Bibliography = 5 titles.) (Includes detailed confusion matrices of 52 consonants, including consonant clusters).

FINAL TECH. REPT., CONTRACT AF19(604)6179
ESD TDR 62-5, January 1962

The background and accomplishments of one year's research on International Language for Aviation are summarized, for the period 1 March 1960 to 28 February 1961. Included are abstracts of the nine research reports produced under the contract.

EAD-TDR-62-14

INTERNATIONAL LANGUAGE FOR AVIATION. A Review of Air Force Sponsored Research from 1952 to 1961, by Stephen E. Smeltz.

Unclassified Report

The administrative provisions for this research are briefly reviewed. In Part I, reports of research are categorized and discussed under three topics: Communication in English with non-native English speakers. Comparative effectiveness of ICAO and US-UK phraseologies. Operational communications. Voice transmission of numerals. Basic and theoretical findings. Miscellaneous secondary developments. A bibliography of 74 references comprises Part II. An annotated bibliography of all reports, arranged by contract, appears as Appendix I. Reviewed and approved for publication.

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